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PEDIATRICS

By VARIOUS AUTHORS

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VOLUME I

With 284 Illustrations

PHILADELPHIA AND LONDON
W. B. SAUNDERS COMPANY

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W. B. SAUNDERS COMPANY
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PREFACE

This system of pediatrics is a collection of monographic treatises on subjects of interest in the diseases of infancy and childhood. While there are many excellent text-books and monographs on the general and special subjects of children's diseases in the English language, the information here collected should be of value to the practitioner, student and teacher alike.

Preparations were made for the publication of these volumes early in 1914. Shortly after the authors had been selected and the assignments distributed, the Great War distracted the attention of the whole world from the works of peace, and every one's interest became absorbed in wartime measures. Very little progress with the publication was made during those fateful days and when, in 1917, America entered the war, the work was completely interrupted. Since the close of the war, however, the contributors have rallied to the support of the editor and publishers and have given unstintedly of their time and labor to bring the publication to successful completion. The earlier contributions have been revised and in some instances wholly rewritten to bring them up to date.

As may be observed from the short historical reference to encyclopedia publications which follows this introductory note, no extensive compilation of pediatric knowledge has been published since the appearance of Keating's "Encyclopedia on Children" which appeared in 1889. During the thirty-three fruitful years which have elapsed since the publication of Keating's epoch-making series of essays many changes and advances have occurred in medical knowledge; it has seemed timely and fitting, therefore, that a renewed attempt should be made to collect in monographic form the material which represents the fundamental knowledge of pediatrics. This I have attempted to do, and whatever labor it has cost, I feel I have been rewarded in the encouragement and coöperation of the distinguished workers who have assisted in making these volumes possible. Such a collection of essays should be of value not only because of the known facts which are presented but also because it will serve to indicate gaps in our knowledge and I have felt a satisfaction in the thought that the volumes would stimulate clinical and research work, especially by the younger men of English-speaking countries.

In addition to the discussion of the internal diseases of children, subjects of surgical interest have been introduced, because after all a child who is sick may require medical or surgical treatment or both, and a well-trained physician not only desires but is compelled to know when surgical treatment is indicated and the manner of its application.

The medical attendant may not himself be a trained surgical technician but it is important that he should recognize surgical conditions and seek surgical advice when it is required. Surgery of childhood differs somewhat from that of adults, since conditions arise in infants and young children which do not occur or which are rare in later life, and there are points of difference in surgical anatomy, surgical pathology, and surgical technic, as well as in surgical diagnosis, which are emphasized by the contributors to these books.

During the years which have passed since our work was begun, Drs. Mortimer Frank, Robert Krost and J. Louis Schwartz have been called by death before the completion of their contributions. Dr. Stanton Friedberg died shortly after he had contributed his manuscript on "Bronchoscopy and Esophagoscopy."

It was originally intended to include a number of chapters on orthopedic surgery but this has been undertaken under separate editorial management and it is proposed to publish these papers in a separate volume.

Finally I would express a deep sense of obligation and appreciation to the writers who have contributed these monographs. Those of us who know the arduous labors of the average medical man of today know best how much self-sacrifice and toil are entailed in the preparation of these papers. I desire to thank Messrs. W. B. Saunders and Company, the publishers, for their great helpfulness in every detail and their kindly spirit. I desire to make special mention for helpful suggestions received from Drs. Fielding H. Garrison, John Howland and Morris Fishbein. I am also indebted to Dr. William J. Corcoran who has rendered valuable aid in arranging the manuscript and in the reading of proof; and to Drs. Johanna Heumann, I. H. Tumpeer and Alice Williams who have assisted in various ways.

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Chicago, Ill.

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ENCYCLOPEDIAS WHICH REFER TO THE DISEASES OF CHILDREN. AN INTRODUCTORY ESSAY

By Isaac A. Abt, M.D.,

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Although the name encyclopedia was not applied until the 16th century it is recalled that composite books containing all the knowledge of the period were published as early as that of Hwang-ti (2698–2599 B.C.) This Chinese Emperor and philosopher promulgated, in a system of internal medicine, a peculiar doctrine which gave personality to the intimate relations of the human organs. Of the Egyptian papyri, that of Ebers, about 1553 B.C., is most complete in its recipes and directions for the treatment of various diseases, and that of Smith, about 3000 B.C., recently translated, is most important for its age and for its rationality. It is hardly necessary to describe completely these works of which so much has been written; and this is also true of the medicine of the Bible and the Talmud. These extensive compilations of religious thought with rules for hygienic conduct are especially noteworthy in the attention paid to the care of the mother and the hygiene of the newborn.

ORIENTAL MEDICINE

Ethnologists know that with the development of every race and nation medicine and the healing art assume a conspicuous place in the life of the community. It is not surprising to find that even among the writings of the ancient Indians, such as the Veda and other sacred books, portions by the two physicians, Charaka and Susruta, 1000 B.C., had an important place. The frequent application of cold water, a rational hydrotherapy, and fantastic charms, incantations and extraordinary superstitions associated, for example, with the color of drugs, mark the medical literature of this epoch.

GREEK AND ROMAN MEDICINE

The Hippocratic collection of writings, as pointed out by Neuburger comprises an intersection of all previous tendencies in medicine, united as an interwoven thread, stretching backward into antiquity and forward to the present day. Whether the work of Hippocrates, a single genius, or the motley heterogeneous output of generations, this notable collection must be considered as representing the inspiration of a master.

Following the Hippocratic writings by some 300 years are the works of Celsus and the collections of Pliny, the former basing his writings on the collection of Hippocrates and including also the medicine of the Semitic peoples, the latter presenting more or less loosely combined facts. In Pliny's writings the original references to scurvy, superfetation and atavism are especially noteworthy for the disturbances of infancy. Equally interesting, moreover are the satirical shafts of wit aimed at the physician which also characterize the writings of other philosophers of the period.

Soranus of Ephesus, 100 A.D., was a prolific writer. Of his numerous manuscripts those on the care of the newborn, the nutrition of the infant, the selection of the wet nurse, and on gynecology and obstetrics are of importance as references to the early literature on pediatrics. In fact, Sudhoff has said of him, "What Celsus' work signified for medicine and surgery, this work of Soranus signified for gynecology, obstetrics and pediatrics in the ancient literature."

The outstanding treatises of the medicine of the middle ages are based on the important works of Galen who commenced practice in Rome about 164 A.D. His compilations were extensive and his therapeutics notable for their dogmatism. While the names Celsus and Galen may be familiar, Oribasius, Paul of Ægina, and Ætius of Amida are not so well known, although each is credited with a great encyclopedia of the medical knowledge of his day. Oribasius was one of the last of the Alexandrian school. His larger work was too bulky for general use, so he wrote a summary or synopsis which was said to have been for the use of his son. This synopsis continued for a long time to be the source for medical information for physicians of the Byzantine and Middle Ages. It has been thought that by writing the synopsis he distracted attention from the ampler work. The writings of Oribasius, Paul of Ægina and Ætius have been made the subject of an essay on plagiarism by Sir Clifford Allbutt, and yet the ability to choose with judgment is in itself a fine art.

ARABIAN MEDICINE

In the Fitzgerald lectures recently delivered by Sir William Browne, an erudite and beautiful exposition of Arabian medicine, mention is made of a work of medicine and natural philosophy written about 850 B.C., to which Ali-ibn-Ribban, the author, gave the modest title "Paradise of Wisdom." The fame of the Arabian scientist rests not so much on this work, however, as on the fact that he was one of the teachers of the great physician Rhazes. The latter, most important among Moslem physicians, wrote an extensive treatise, particularly noteworthy for its citation of case histories, which is a classic in early Arabian medicine. In Persia 100 years later appeared the prince of physicians, Avicenna. He has been well called the Galen of the Arabs for he was a voluminous writer of a systematic type of mind. The Canon of Avicenna became the most important text in the Moslem world and superseded the works of Rhazes and other earlier writers. From the twelfth to the seventeenth centuries it continued to be the guide of medical students in European universities and Avicenna became more famous than Rhazes. Up to about 1650 the Canon was still used as a text-book in the universities of Louvain and Montpellier.

SCHOOL OF SALERNO

During the Middle Ages, from the sixth century onward, all medical activities were gradually circumscribed by the church, especially by the monks who were well educated and who were able to read not only their own but also foreign languages. The two chief literary works of the school of Salerno, which dominated medicine during the next half century, are the "Compendium Salernitatum" and the "Regimen Sanitas." The "Compendium" is the first example of a complete text-book of medicine and surgery in which many experts work under the direction of a single editor. Many subjects were considered including venesection, the pulse, the urine and fever all of which were on Hippocratic principles. The "Regimen Sanitas" was a medical poem. Verse-making in medicine became a genuine medieval fashion among Christian writers of this period. The object often was to facilitate committing the subject to memory. The "Regimen Sanitas" was undoubtedly a composite work, various editions being made from time to time.

Up to the 16th century, therefore, while the actual knowledge of medicine as a science developed but little there were gradually being accumulated a vast amount of empirical observations and data and attempts to interpret natural phenomena and the causes and nature of human diseases in terms which would convey such knowledge to future generations. Knowing nothing of the circulation of the blood, the physician was compelled to account in a vague and indefinite manner for the phenomena related to the circulation. The limitation placed on the acquiring of the fundamental knowledge of anatomy, physiology, and other basic sciences permitted only limited observations and stimulated speculative philosophy.

Each encyclopedist of this early period borrowed liberally from his predecessors and added thereto the small amount of observation and a larger amount of original philosophy which represented his own contribution. Even the men of genius plundered largely. Among the summists and copyists of Byzantium such natural masters as Soranus and Galen plundered largely, literally and anonymously. The Arabs transcribed the Greeks, the Greeks the Latins, and the Latins each other. Allbutt suggests that Celsus may have named his sources so generously because he was a layman. Pliny helped himself lavishly to Dioscorides but makes no acknowledgments to him.

With the natural intermingling of nations resulting from commerce and warfare the writings of physicians of one nation were liberally transferred into the literature of other nations. Medical plagiarism is not an innovation of modern times. Perhaps the word "plagiarism" is harsh, for after all no man can in his own life time accumulate sufficient experience to write a complete exposition of even a single group of diseases. It is the mark of rationality and progress to benefit by the experiences of the past.

THE SIXTEENTH CENTURY

Collective writings in the modern sense did not appear until about the sixteenth century, when a huge "gynecia" or encyclopedia of gynecology was issued by Caspar Wolf (1532–1601) of Zurich, in 1566. This was later enlarged by Caspar Bauhin (1550–1624) of Basel, in 1586. These two compilations of the best that has been written on the subject were afterward reprinted in one volume by Israel Spach, of Strassburg, in 1597. Encyclopedic treatises on medicine by many authors, not unlike the works written on the cooperative plan in our own time, were a special feature of the medicine of the Renaissance and of these we may mention, in addition to the Basel encyclopedias of gynecology, the Aldine "Medici Antiqui Omnes" (1547), the "Medicæ Artis Principes" of Stephanus (1567), the Venetian anthology of mineral waters, "De Balneis" (1553), the Gesner collection of surgical treatises (Zurich, 1555) and the medical dictionaries of Symphorien Champier (1506), Lorenz Phryesen (1519), Henri Estienne or Stephanus (1564) and Jean de Gorris or Gorræus (1564). With these may be classed the concordance of expressions from Erotian by Eustachius (1566), the "Variæ Lectiones" (1571) of Geronimo Mercuriali and the "Œconomia Hippocratis," a similar exegesis by Anutius Fœsius (1588).

THE SEVENTEENTH CENTURY

In the seventeenth century various encyclopedic works were compiled. In 1677 J. J. Hoffmann published in Basel his "Lexicon Universale." This was more in the nature of a dictionary, in the modern sense, though it gave a summary of the most important facts of the arts and sciences as they were understood at that time.

Among other works of this period were the "Biblioteca Universale" of Coronelli. It was to have appeared in thirty-five volumes, though only seven were published (Venice, 1701–1706).

A German encyclopedia, which appeared during this period, was a complete collection and was named after one Zedler, the publisher who produced the work. It was entitled "Grosses vollständiges Universal Lexicon aller Wissenschaften und Künste."

Other books of this period which were dictionary compilations were Hübner's "Konversationslexika" (1704), and the work of Brockhaus (1796–1808), the encyclopedias of Ephraim Chambers (1728), Diderot (1751–1752), Voltaire's, "Dictionnaire philosophique," 1784 and the "Encyclopedia Britannica" (1768–1771).

The "Encyclopedia Britannica," in three volumes, was completed by a society of gentlemen in Scotland in 1771.

No work of reference has been more useful and successful or more frequently copied, imitated and translated, than that known as the "Konversationslexikon" of Brockhaus. It was begun in 1796–1801 by D. Gotthelf Renatus Löbel.

Diderot published his "Dictionnaire universal de medicine" in six volumes in Paris, 1746–1748. This publication was a translation of the celebrated "Medical Dictionary" of Dr. Robert James, inventor of fever powders (London, 1743–1745). It consisted of three volumes, 3257 pages and 98 plates, comprising a history of drugs, chemistry, botany and natural history so far as they relate to medicine, and contained a historical preface of 99 pages.

THE WORK OF TOBIAS

Levinson recently abstracted the work of Tobias which belongs to the latter part of the seventeenth and the early part of the eighteenth centuries. References are quoted here liberally because they indicate the nature of the encyclopedic writings of the period. Tobias was a wandering practitioner of medicine who studied in different countries. He began his study of medicine at Krakow, continued his course at Frankfort, obtained his degree at Padua, practiced in Poland, was attending physician to five sultans, wrote his book in Adrianople, published it in Venice, held a professorship in Constantinople, and died and was buried in Jerusalem. His *wanderlust* brought him into contact with the greatest authorities of his age and enabled him to study the diseases of the different countries in their nativity. He was thoroughly conversant in nine languages; he knew their daily usage, their literature, and their science.

The close of the sixteenth and the beginning of the seventeenth centuries were crowded with events in the field of science in general, and of medicine in particular. Not many years before the birth of Tobias Lord Bacon promulgated the inductive method of philosophy which exerted a profound effect on religious and philosophic thought throughout the entire world, and Copernicus announced the view of the solar system that moved the earth from its place. It was in the sixteenth century that Vesalius dissected human bodies and thereby put anatomy on a scientific basis, and in the early part of the seventeenth century Harvey enriched the world with his discovery of the blood circulation.

During these years Tobias worked indefatigably on a variety of medical problems. The results of his labors were compiled in his most representative book, "Maaseh Tuviah." The book is encyclopedic in nature. It contains thoughts on religion, something of astronomy, geology, chemistry, and indeed a little of everything, but the major part of its contents is devoted to medicine. Such was the popular way of writing in his day, and indeed, books such as his served a very useful purpose. They furnished a mirror of the views of the author and of his contemporaries not only on the main subject of the treatise, but on every other human project that enlisted the interest of thinking men. It would be interesting to follow Tobias through his many by-paths, were we not especially concerned with his contributions to medical literature. (Levinson, "Medical Cyclopedists of the Seventeenth Century.")

Encyclopedias in the modern sense originated in England. France soon followed although her publications were written in a more philosophic spirit. In Germany, during the last century, publications almost too numerous to mention have been issued in which treatises on every possible subject were collected and treated in detail. These works were encyclopedic in that they were compilations of various subjects discussed by numerous authors. In 1834 publication of Schmitt's "Jahrbücher" was commenced and they have continued for many years to furnish abstracts and important bibliography.

SYSTEMS OF MEDICINE

Among the most important of the general medical systems is that of v. Ziemssen. The first volume was published in 1876. In this collection the whole field of internal medicine and infectious diseases was covered in a masterful way. Many of the monographs emanated from the medical leaders of the time, such as Liebermeister, Curschmann, Oertel, Schrötter, Naunyn, v. Ziemssen, Steiner, Steffen, Fraentzel, Jürgensen, Rindfleisch, Quincke, Zenker, Kussmaul, Erb, Senator, Birch-Hirschfeld and a host of others. This system was the classical reference book for several decades, and while the material advances in clinical medicine, pathology and physiological chemistry have rendered these volumes obsolete, nevertheless the clinical observations and the descriptions of disease would in many instances be valuable as reference for the modern student of medicine. The authors who contributed to this series were masters in the art of clinical medicine.

The Nothnagel "System," which is a very large aggregation of volumes, covers similar material to that of v. Ziemssen's, though in a more modern period. The monographs are in most instances classical contributions and continue to be of value to the present-day student and investigator.

Another system, less voluminous, is that of Ebstein and Schwalbe. More recently the "Handbuch der innere Medezin" by Mohr and Staehlin has been compiled, and still more recently that of Friedrich Kraus and Theodor Brugsch.

The unique publication by Lubarsch and Ostertag on "Ergebnisse der allgemeinen Pathologie des Menschen und der Thiere" is a collection of volumes published annually, reviewing in a most comprehensive manner the additions to pathologic knowledge and constituting a valuable book of reference. Penzoldt and Stintzing compiled a system of therapeutics in 1894.

AMERICAN AND ENGLISH SYSTEMS OF MEDICINE

In America a system of practical medicine was edited in 1885 by William Pepper, assisted by Louis Starr, and in 1907 Osler's "Modern Medicine," by American and foreign authors, was published. The latter contained many papers of striking merit and has served as an important reference work for students, teachers and practitioners. In addition, numerous encyclopedic publications on surgery and other branches of medicine have been published in America.

Allbutt's "System of Medicine," an English publication which appeared in 1896, contains papers by English and American authors. It is one of the most valuable of the modern English encyclopedias. The "Twentieth Century Practice of Medicine" was edited by Thomas L. Stedman of New York. It consists of 20 volumes and contains many interesting and valuable contributions. Among other encyclopedic books published during the last two decades may be mentioned the "Reference Handbook of Medical Sciences," the first edition of which appeared in 1885–1893, the third edition in 1913; systems of therapeutics edited by Hare in 1891, Solis-Cohen in 1902, Musser and Kelly, 1911–1917, and Forchheimer in 1906. Barker's monographs on internal medicine appeared in 1916, and the "Encyklopädische Jahrbücher der Gesamten Heilkunde," edited by A. Eulenburg in 1907.

SYSTEMS OF PEDIATRICS

In pediatrics the number of extensive compilations is not large. About 1773 in Leipzig a collection of interesting treatises was published which gave in detail some of the clinical disorders of infancy and childhood. This publication consisted, however, of a series of papers containing clinical descriptions. In 1811 a series of essays appeared in France entitled, "La Clinique des Hôpitaux des Enfants et Revue Retrospective Medico-Chirurgicale et Hygienique; publices sous les auspices et par les medicine et chirurgiens des hôpitaux consacrees and maladies des enfants."

Among the outstanding systems are Gerhardt's "Handbuch der Kinderkrankheiten," 1877–1893; John M. Keating's "Cyclopedia of the Diseases of Children," 1889–1890; J. Grancher and J. Comby's "Traite des Maladies des Enfants," 1897; Pfaundler and Schlossmann's "Handbuch der Kinderheilkunde," 1906; Anderodias and Cruchet's "La Pratique des Maladies des Enfants," 1909. Gerhardt's Handbuch was an epoch-making publication which collected the most important information on the subject and for many years stimulated study and research. Henning's contribution in this publication was eagerly read by the specialist and consulted by those who desired information on the history and development of the pathology of childhood. Henke's dissertation on the anatomy of childhood has long been considered a classic. Vierordt wrote on physiology, contributing 288 pages of the most carefully assembled facts; this chapter is an important source of physiologic knowledge concerning the child. To A. Jacobi was assigned the hygiene of infants and children, and the subject was most carefully and thoughtfully treated. C. Binz wrote on therapeutics and Pfeiffer on infant mortality. In the same volume Pfeiffer wrote on vaccination and A. Baginsky on school hygiene. Rauchfuss of St. Petersburg considered hospital buildings, hospital administration and equipment, and he also contributed a chapter on congenital heart disease.

It is not necessary to give in detail all of the subjects considered, but perhaps one of the most important papers was that of Widerhofer and Kundrat on the gastro-intestinal diseases of infancy. Many new theories have arisen since that time. New information in chemistry and pathology has been added to this group of disorders, and the classification proposed by Widerhofer has been changed time and again, but the keen clinical observations, and the carefully expressed descriptions have remained as a basis for all subsequent discussion of this disease group. The Gerhardt "Handbuch," a pioneer in modern pediatric writings, has been a real force in developing the study of pathology in infants and children.

Keating's "Encyclopedia" was published in 1889 in four volumes and ten years later a supplement appeared. An array of the most distinguished pediatric teachers and thinkers in America contributed to this work. A. Jacobi wrote the introduction, James Finlayson, of Glasgow, made a valuable contribution on diagnosis, Thomas M. Rotch, of Boston, wrote the chapter on infant feeding, W. B. Cheadle, of London, discussed rheumatism and acute and chronic endocarditis, Thomas Barlow described rickets and scurvy, William Osler contributed the chapter on congenital heart affections, L. Emmett Holt discussed diarrheal disorders, acute and chronic, and J. P. Crozer Griffith described diseases of the blood and the blood-making apparatus. The other distinguished men who wrote for this book typify the most advanced thought on their special subjects. The volumes had an important and stimulating influence on English-speaking physicians, and served to call attention to the entire field of pediatrics by presenting knowledge in a readily accessible form. The work awakened a keen interest in the pathology of childhood and Keating's treatise was, for many years, the standard reference book for the specialist in pediatrics as well as for the general practitioner in medicine.

The Pfaundler and Schlossmann system, published in German, has been translated into English. The first volume contains a paper by Franz Hamburger, of Vienna, on general pathogenesis and pathology of childhood and deals with the general aspects of disease. A very interesting and painstaking chapter is that of Professor M. Pfaundler, now of Munich, on the symptomatology of children's diseases. He sets forth in a very elaborate tabular form the symptoms which may occur in the various diseases.

The contributions of G. Bendix on general prophylaxis, H. Neumann on therapeutics and of Prausnitz on mortality and morbidity are worthy of careful study. Following this are valuable papers by Raudnitz on milk, two papers by Camerer, one on metabolism and nutrition during the first year of life, and another on children's growth in weight and height. The contributors constitute the leading authorities in Germany and Austria and, while these volumes were published sixteen years ago, they still constitute an authoritative reference work. Supplementary volumes have been published, one on surgery and orthopedics and another on nervous diseases, and one on the eye and ear and speech disturbances.

SPECIAL WORKS OF PEDIATRIC INTEREST

In 1905 "Die Deutsche Klinik" included a series of essays on diseases of children on selected topics. Among many contributors of distinction Czerny wrote on the feeding of children, Monti on the most frequent infections of the buccal mucous membrane, Soltmann on scrofulosis and tuberculosis of children, Escherich on acute digestive disturbances of infants, C. Keller on disease of the newborn, and Heubner on measles.

In 1913 appeared the first volume of a book entitled "Handbuch der allgemeinen Pathologie und der pathologischen Anatomie des Kindesalters," edited by Brüning and Schwalbe, both of Rostock; the book considers the pathology of infants and children and also discusses at considerable length the various malformations. In a special chapter the subject of comparative pathology is treated in which the diseases of young animals are compared with those of young children. The infectious and parasitic invasion of young animals, as well as the malformations and the tumors, are discussed. Nearly every tissue and organ is studied in this way by Jost and Koch. Publication of this work was interrupted by the war and at present (1922) it is not complete.

A composite volume on "Diseases of the Nervous System" by Bruns, Cramer and Ziehen, which appeared in 1913, contains detailed descriptions of the various nervous and mental diseases incident to infancy and childhood. It is undoubtedly one of the best reference books of its kind.

A very valuable book on the hygiene of the child was issued by W. Kruse and Paul Selter in 1914. This work considers growth and development, cause of disease, infantile nutrition, protection against heat and cold, and hygiene of the environment. Another chapter deals with exercise of the body and mind, hygiene of infancy, school hygiene, hygiene of crippled children, training of defective and nervous children and a variety of other subjects. The treatise is a valuable collection of monographs for those who are especially interested in the hygiene and diseases of infancy and childhood.

The "American Text-book of Diseases of Children" published in 1898 under the editorial management of Louis Starr of Philadelphia, contains valuable contributions by American authors of note. H. Dwight Chapin wrote the chapter on hereditary syphilis. There are excellent chapters on infectious and digestive diseases. Victor Vaughan, in a notable contribution on the diarrheal diseases, was undoubtedly one of the earliest writers who considered that the gastro-intestinal diseases of infancy may be caused by food disturbances. The late Sir William Osler wrote the chapter on tuberculosis in infancy, and his paper was one of the best on the subject accessible to English readers at that time. The chapters on nervous diseases in children were carefully considered, notably the papers of Frederick Peterson, Charles K. Mills, Allan Starr and other distinguished authors.

A composite book entitled the "Practice of Pediatrics," edited by Walter Lester Carr, was published in 1906. It contains many important contributions and in addition to the American authors, papers from several eminent English clinicians are presented.

A unique collection of books entitled "Collectanea Jacobi" in eight volumes was edited by William J. Robinson. These volumes contain the various publications of the distinguished pediatrician, his medical essays, his public addresses and his discussion of public problems. These papers teem with medical wisdom, philosophic thought and an unusual human understanding.

An English book on "Diseases of Children" by various authors, edited by Garrod, Batten and Thursfield, contains a splendid series of contributions with excellent clinical descriptions of the most commonly encountered diseases of children.

Feer's recent work, "Lehrbuch der Kinderheilkunde," published in 1911, is a composite book and up to the present time has gone through seven editions. The contributors are among the most active and best known German pediatricians. Finkelstein, Ludwig Meyer, Pfaundler, von Pirquet, Noeggerath, Ibrahim and Moro contribute the various chapters.

Kelynack in 1908 published a book on "Tuberculosis in Infancy and Childhood" by numerous English and some American authors. It is a brief treatise covering about 350 pages. The same author has edited a book on medical examinations of schools and scholars with the collaboration of a number of British writers, though there are some foreign contributors who detail school examinations as carried on in their own countries. The edition contains contributions from Switzerland, Sweden, Norway, Denmark, France, Germany and several from leading authorities in the United States.

The book by Grancher, Comby and Marfan, consisting of five volumes, covers the general field of pediatrics and includes contributions by a brilliant array of French and foreign scholars. Ballantyne of Edinburgh, Barlow of London, Bokay of Budapest, Epstein and Fischel of Prague, and Escherich of Vienna, are among the contributors.

"La Pratique des Maladies des Enfants," edited by Apert, Cruchet and Carriere, is a comprehensive system of pediatrics by leading French clinicians. It was published in five volumes in 1912 by J. B. Balliere.

CONCLUSION

In attempting to make a rapid survey of the encyclopedic literature covering a vast period of time it has been possible to mention only the outstanding collections. To do full justice to any of them would require more detailed accounts and descriptions of greater length. It has been my purpose to give a brief survey of the rise, existence and development of this kind of literature as well as to consider its influence on medical thought and medical progress.

For ages medicine was in a chaotic state; such science as existed was almost hopelessly mixed with empirical deduction and inference, unchecked by rational methods of control. A glance down the centuries from the time of Hippocrates, the first real physician to conceive the idea of bringing together the collected wisdom of the preceding ages, reveals many encyclopedic volumes which influenced the progress of contemporary physicians and stimulated succeeding generations toward greater achievement.

The outstanding lesson to be learned from such a historical review is the fact that preeminent thinkers and leaders—men of real genius, do not appear frequently. Hippocrates had many eminent disciples, yet for many centuries no great discovery was made and no new light was shed on medical problems. Not until the 16th century did the scientific spirit of experiment, observation and investigation permit medicine to emerge from the darkness. The development of physiology, anatomy, pathology and eventually of chemistry lifted the healing art out of the abyss of ignorance, philosophic speculation and uncertainty and placed it on firm ground which permitted progressive and rational development.

Great geniuses—leaders and pathfinders—are few and far between. They cannot be manufactured by pedagogic methods, either ancient or modern. They are not the product of any system of education; they are born great and remain so, and their light and lustre illuminate the field by revealing hidden facts and by uncovering what has seemed impenetrable. It falls to lesser mortals to give such aid and encouragement as they can.

A SYSTEM OF PEDIATRICS

CHAPTER I

HISTORY OF PEDIATRICS

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Pediatrics as a specialized branch of medicine had no real existence before the middle of the nineteenth century, hence the literature of the history of the subject is meager. Its earlier history is only a small part of the main current of internal medicine.

Carl Hennig's introductory chapter in the Gerhardt *Handbuch* (1879, I, 11–50), the unsatisfactory fragment by Wolf Becker in the Puschmann *Handbuch* (1905, III, 992–1000), the admirable addresses of Theodor Escherich and Abraham Jacobi at the St. Louis International Congress (1905), the charming history of infantile hygiene by Auvard and Pingat (1889), S. S. Adams' study of American pediatric literature (1897), Hermann Brüning's illustrated history of artificial nutrition of infants (1908) and his historical review of pediatrics (with an excellent bibliography) in Brüning and Schwalbe's *Handbuch* (1912, I, 1–20), Ludwig Unger's translation of Metlinger (1904), the studies of Greek pediatrics by T. Kroner (1876–7) and J. W. Troitzky (1900), Sudhoff's investigation of Cornelius Roëlants (1909–15), Forsyth's history of infant feeding from Elizabethan times (1910), Abt's history of the classification of gastro-intestinal diseases (1912), Jacobi's history of American pediatrics (1913), L. E. Holt's history of infantile mortality (1913) and Jacobi's subsequent papers on pediatrics in New York City (1917) make up almost the entire literature of any importance. An indispensable bibliography of pediatrics (up to 1849) was published by F. L. Meissner in 1850. The full literature of the subject, up to 1898, is listed in the Index Catalogue of the Surgeon General's Library under the headings "Children" and subdivisions (II, 936–957; 2. series, III, 422–472); "Infant (New-born)" and "Infants" (VI, 821–860; 2. series, VII, 891–930); and "Pediatrics" (2d series, XII, 717).

In the present study I shall endeavor to outline the subject from the viewpoint of the general historian and bibliographer rather than that of the professional pediatrician, but I shall neglect the customary procedure of attempting to embrace the whole history of medicine in a narrative of this kind. There are many things in the secular and cultural history of races and nations which are of great moment in the history of pediatrics. But it is reasonable to suppose that any well equipped practitioner or specialist of today is acquainted with the general trend of the history of medicine, and my own experience tells me that it will only impede his progress to pester him with irrelevant data about the past. Biographical details about earlier physicians, whose relation to pediatrics was only oblique or incidental, will not be given and will be otherwise confined to men who have devoted their lives to the subject.

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[*] Published by permission of the Surgeon General, U. S. Army.

Hennig has remarked that the science of children's diseases is the last and latest addition to the science of disease in general. For this strange phenomenon he assigns two causes: First the intimate relation existing between mother and child at the start, making obstetrics, gynecology and pediatrics inseparable; second, the difficulties encountered in recognizing diseases in speechless young children or in eliciting clinical information from them before the days of expert precision in diagnosis and autopsy.* This is a common excuse of all the earlier pediatricians, from Walter Harris down. The Swedish bills of mortality, even as late as Rosenstein's day, listed 9,783 children as dead "from unknown causes." But a far more potent factor was also operative, namely the absolute neglect of the proper care and hygiene of infants among savage and primitive peoples everywhere, and even among highly civilized peoples in the immediate past. Few realize, indeed, that it was a main object of the Greeks, Romans, Arabians and some later peoples to destroy rather than to save a majority of newborn infants, partly for economic reasons, partly from inherent selfishness. It is literally true that, among primitive races (in space) and ancient peoples (in time), the newborn child was often predestined to be murdered. Among modern "civilized" peoples, for a long period, the child, if of poor or humble parentage, was predestined to be maltreated, starved and tortured. To appreciate this fact, let us glance at the **ethnic and social status of the child** in space and time. In all prehistoric and primitive phases of human development, the child is regarded as a negligible factor. In primitive society, the struggle for existence obtains in full force; the individual is sternly sacrificed for the welfare of the tribe or race; the strong wear down the weak; the weakest inevitably go to the wall. Blind forces flow, as in physics, from higher to lower potentials. The infant, being the weakest configuration of human protoplasm conceivable, stood, as Payne says, "naturally low in the scale of value."† Among primitives, infanticide, abortion, cannibalism and ritual sacrificing of children are the rule; solicitude for their preservation is the exception. Savage children are mutilated by tattooing, scarification of the face and body, artificial deformation of the skull, the face or the extremities, and ritual operation upon the genitals. Twins are frequently killed as something unnatural or uncanny, or upon the supposition that one of them is a sort of monstrous superfetation from adulterous intercourse. Children born on "unlucky days" are slaughtered, as also children born headfirst or in footlings presentation, children born with teeth, a caul or other abnormities, children born in stormy weather, children that sneeze directly after birth; in fact, almost any pretext for infanticide is seized upon, in particular the crude Malthusian notion of limiting the population by sacrificing all children born in excess of a statutory number for a given family. The "pigeon pair" (*das Zweikindersystem*) is as popular with the savage as with the *civilisé* of today. It has been shown that prolificity varies with the amount of food-supply and the productive value of offspring. Limitation of offspring is usually determined by scarcity of food and creature comforts, but religious ardor, alleged solicitude for the welfare of the race, anxiety lest the child suffer as a charge upon the community, economic reasoning, have been in each case a cloak for cruelty and murderous feeling in the savage as in the civilized. The only protection the child has in the savage state originates in maternal feeling, and the mother is invariably subjected to the male. Prosper Mérimée observed that "*La femme à l'ètat sauvage est toujours laide.*" How much more is this true of the savage child. The distrustful, sometimes hostile faces that look out from the pages of Ploss's "*Das Kind*" tell their own tale. Girls had invariably a harder fate than boys. The story of the routine sacrifice of female infants is one of the saddest pages in human history. Even among the Greeks and the Romans, the murder of children and the glorification of the male element, to the exclusion of every thing else, localizes and diagnoses a latent barbarity. Plato said that the *fœtus in utero* was to be regarded as an animal. Plutarch declared the destruction of one's own children to be ofttimes a great and virtuous action. It is significant that Egypt and Babylon, the two ancient civilizations which were kindest to children, were of the matriarchal type.

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* C. Hennig, Handbuch der Kinderkrankheiten (Gerhardt), Tübingen, I (1877), pp. 1–2.

† G. H. Payne, "The Child in Human Progress." N. Y. (1916), p. 5. This book, while somewhat one-sided in its enlargement upon the cruelties practised upon children through the ages, is still a very valuable summary.

The charms and taboo practices employed to ward off evil spirits from the unborn child, such as the couvade, probably originated, not from parental sympathy, but from the savage's innate fear of intangible evils and of the unknowable. Tekonymy, the re-naming of a parent after his newborn offspring, does not spring from regard for the offspring but from the inflation of parental self-esteem upon possessing offspring. The various mutilations of the child's body*—boring holes in the nose, lips and ears, flattening the nose, deforming the skull, feet and fingers, knocking out or sharpening the teeth, circumcision, clitoridectomy, infibulation, tattooing, scarification—are superstitious rites, initiating the sexual life, preparatory to marriage, or even regarded as improving the child's appearance. All are animistic in theory, but hardly expressive of human sympathy. The casting of horoscopes for the child, the hanging or secreting of amulets about its person, the planting of trees in its favor, and similar rites, have the same tendency and significance.† Lane (Modern Egyptians) records that well-to-do women of Egypt dress their children poorly and shabbily "to guard them from the evil eye."

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* On the subject of artificial deformation and mutilation of children among savage and civilized peoples, see J. H. Porter, Ann. Rep. Smithson. Inst. (1887), Washington, II (1889), pp. 213–235; and A. Chéreau, Mutilations ethniques, Dict. encycl. d. sc. méd. (Dechambre), Paris, 1876, 2, s., xi, pp. 153–167.

† See H. Ploss, "Das Kind, 3 Aufl." Leipzig 1911–12. 2 v., *passim;* and Elsie Clews Parsons, The Family. N. Y., 1906, pp. 95–111.

"The attitude of the tribe or nation towards its young," says Payne, "is also a barometer of progress." At the beginning of his book on "The Child," he points out that the lowest human tribes are less human in sentiment for their women and their offspring "than certain beasts and birds." "The instincts of the lower animals," said Darwin, "are never so perverted as to lead them to regularly destroy their own offspring or to be quite devoid of jealousy." The normal causes of **infanticide among savages** are either superstition or fear of famine. The Papuan family is restricted to two children. Infanticide is very prevalent in the coral-reef islands of Polynesia, where the food supply is always an uncertain quantity. Twins are immediately killed among the South Australians, Aruntas, the Kaffirs and the West African negroes. It is dishonorable for women to have twins in the Benin territory, whence twin-bearing women are roughly handled. In more specialized communities, children are sacrificed as an offering to the gods. Here religion becomes a kind of sanctioned blackmail of humans by gods and their organized votaries, or else a cloak for fanatical self-exploitation or some equally selfish end. The real reason is that there is not enough food to go around. To nomadic tribes, indeed to all whose principle of action is Kipling's "He travels fastest who travels alone," children are invariably an encumbrance. In old and (up to recent times) almost stationary civilizations, such as China, India and Japan, infanticide, the routine sacrifice of female children and the selling of children into slavery were consequent upon the deposal of the primordial matriarchate, and grew with increasing density of the population or latterly with occasional periods of famine and privation. In China, the drowning of infants, especially female infants, is still prevalent in spite of endless imperial edicts. The Jesuits record that up to 232 B.C., children were an asset, the orphan could choose his adoptive parents and there was no trace of drowning, exposure or abandonment. With Confucius arose the idea of male sovereignty, with the child as a subject or chattel. Under Tsin Chi Hoang (232 B.C.), war and famine led to the practice of abandonment and to the drowning of female infants. In the first official document against infanticide (1659), an edict of Choen Tche (1633–62), we read:

> I have heard that the sad cry uttered by these girl babies as they are plunged into a vase of water and drowned is inexpressible. Alas! that the heart of a father or mother should be so cruel.*

Subsequent decrees of 1773, 1815, 1845, and 1848 proved of little avail, owing to the scarcity of food in relation to the density of the population. Some writers estimate that from 25 to 40 per cent. of female infants are drowned annually but the practice is slowly dying out in most localities. In ancient Japan, the sons of a polygamous father were natural enemies and had no claim upon him. Human sacrifice, *e.g.*, to insure that the foundations of a building might be

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* Cited by Payne.

"well and truly laid," was abolished about 3 B.C., but famine sometimes produced cannibalism, and children were legally punished as scapegoats for the crimes of their parents up to the end of the seventeenth century. Chinese ideas and ideals gained ascendency about 552 A.D., and after Confucius came the deposal of the matriarchate by the Samurai and the sacrifice of children to the welfare of their parents. There were eight enactments against the sale of children between 1624 and 1734. The Japanese are fond of children and have no such intense dislike for girls as the Chinese, nor is the population so dense, yet many children were sold during the famine of 1905 and infanticide is said to have been prevalent in connection with the high taxes following the Russo-Japanese War. In ancient India, the Aryans, originally an agricultural people, later a race of fanatical warriors, desired male children to increase the fighting capacity of the tribe. Male children became part of the scheme of wealth. Females were preserved for procreative purposes only. The Laws of Manu declare that "Women are born to bear children." The slaughter of unnecessary children was sanctified in the Mahabharata. The ancient rituals show that female children were doomed at birth. Female infanticide was held to be of divine origin; the real reason for its existence was economic. The chief end of Aryan man being to feed himself by predatory wars and to breed soldiers for this end, women were only tolerated in numbers sufficient for this purpose. Female infanticide, like the suttee custom, was highly prevalent in eighteenth century India. The attempt of Colonel Alexander Walker to suppress it, in 1805, led to a long correspondence of 80 years duration, in which the Indian princes protested vigorously against interference with their religious and social ideas of 4900 years standing. The Infanticide Act of 1871 was the final effort of government to suppress the practice. The ancient practice of sacrificing the first born for ritual reasons is familiar in the Biblical stories of Abraham and Isaac and the daughter of Jephthah. The Arabians, a nomadic desert people, sacrificed their infant and even adult daughters by burying them alive, until the practice was suppressed by Mohammed. The Greeks, in some respects the most intelligent people the world has known, were utterly callous about the fate of children foredoomed to exposure by economic conditions or by the shame of pregnancy in unmarried women.

But there is a good deal of human nature in the world and we must not neglect the brighter side of the picture. The civilizations of Egypt and Babylon, being centered in fertile, plenteous lands, and matriarchal in type, were as we shall see, reasonably fair and decent to the child. This was perhaps also true of the Minoan civilization of Crete, the presiding deity of which was a primordial mother-goddess. There is sufficient evidence that such children as were permitted to survive under stress of economic conditions were not inhumanly treated, even among savages, although there is little evidence of an active sympathy for children. Stevenson said that the South Sea Islanders who practice infanticide and are capable of selling their children into slavery are yet affectionate and patient with them.* Not all of ancient Greece was given over to infanticide and exposure. Ælian records that in Thebes these offences were punished by death.† Mahaffy thinks that the Greek practice of exposure of infants arose in a late period, and from economic motives in an overcrowded civilization.‡ In evidence, he cites the instances of sympathy for children in Homer, Herodotus, Euripides and Thucydides.§ In the sixth Iliad, there is the affecting farewell of Hector and Andromache. The hero bewails the impending fate of his wife and child, and tenderly lays aside his helmet lest the infant Astyanax, "fair as a star," be frightened at his nodding crest. In the subsequent lament of Andromache over the body of Hector, she bewails her widowhood and mourns the hard fate in store for her defenceless child.

Women, particularly great ladies like Helen, Andromache, Hecuba, Penelope, were held in high esteem by the Homeric Greeks and their children no less. There is evident tenderness for child-life in the similes of the Homeric poems. In the fourth Iliad (20), Minerva repels the arrow shot at Menelaus "as a mother drives away a fly from her child when it lies in sweet sleep." In the fifteenth Iliad (361), Apollo overthrows the earthworks of the Greeks as easily as a child playing by the sea tumbles the sandheaps it has made. At the beginning of the sixteenth Iliad, Achilles addresses the weeping Patroclus with winged words:

> "Why weepest thou, O Patroclus, like an infant girl, who running along by her mother, begs to be taken up, and holding on by her dress, delays the hurrying woman, and looks at her with her eyes full of tears, in order that she may be taken up and carried."

Mahaffy emphasizes the strong love of children in the anecdotes of Herodotus, which sympathy is, in all likelihood, "his own or that of his age, even though the naked facts may be the heritage of a previous society." When the oligarchs of Corinth sent ten of their number, in deference to the oracle, to destroy Cypselus, the child of Eltion, the mother, Labda, unaware of their intentions, placed the infant in the hands of one of them; but its smile was so beautiful that the oligarch could not summon brutality to dash out its brains, so handed it to the second, he to the third, until it passed through their ten hands unscathed. When they finally resolved to accomplish the deed, the mother had safely hidden the child in a chest, and after a half-hearted search, they returned to say that they had done all that had been commanded (V, 92). Elsewhere, he tells how a house in Chios, "fell in upon some boys as they were learning to read, so that of one hundred and twenty boys only one escaped" (VI, 27). In another place, he describes a Spartan nurse standing before the temple of Helen to pray that the goddess might make an ugly infant beautiful (VI, 61). Aristotle relates that when the oracle, in punning fashion, commanded the Malians to love the dearest of the dear (*φιλεῖν τῶν φιλτάτον τὰ φίλτατα*), they carried their naked infants about at feasts and kissed them. Themistocles, in Plutarch's Lives, declares that "his boy, who bullied his mother, was the greatest power in Greece: For the Athenians ruled the rest of Greece, Themistocles ruled the Athenians, his wife ruled him, and his boy ruled her." In the tragedies of Euripides, children appear upon the stage to heighten the pathos of a situation. In Thucydides (VII, 29), it is said that the massacre of a whole school of little boys at Mycalessus by a band of Thracian mercenaries was regarded as the outstanding instance of frightfulness in the whole Peloponnesian war, although in Mahaffy's view, the cold historian conceals his own emotions "under the most violent contortions of grammar."* There is thus abundant evidence of a tender regard for children in the ancient Greek civilization, in spite of the fact that exposure of infants was common at Athens, and was justified and almost defied in poetry and the drama, as being the lot of Zeus, Poseidon, Hephæstus, Æsculapius, Atalanta, Ion, Amphion and Œdipus. Let us remember, also, that it is precisely in Greek medicine that we find the only scientific body of pediatric literature of value before the advent of the masters of the eighteenth and nineteenth centuries.

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* Payne, *op. cit.*, p. 44.

† Ælian, Varia Hist., ii, p. 7. Cited by Lecky.

‡ J. P. Mahaffy, "Social Life in Greece from Homer to Menander." London (1913), p. 165.

§ *Ibid.*, pp. 163–169.

Christianity and its votaries undoubtedly did much to elevate the status of the child and to remove its social disabilities. The figures of the Madonna and the Christ Child were enshrined in mediæval art; but it is not until the middle of the nineteenth century that we find any artistic and human feeling comparable with that of the Greeks. In modern civilization, the child is explicitly "the father of the man," the expression of the continuity of the germ-plasm, the means whereby the individual projects and propagates himself or herself into futurity. Ours is "The century of the child," a result partly due to art, partly to science and scientific legislation. About this tiny figure have clustered and concentrated all things that differentiate the altruistic from the self-regarding feelings, the best ethical ideas and sentiments in regard to the proper relations between men and women, the noblest aspirations of our time toward humanitarian and social legislation, some of the finest inspirations of poets, artists and musicians. The religious and legal sanctions of marriage exist solely for the benefit and protection of the child, only incidentally for the "respectability" of the contracting parties. With Rousseau's *Émile* (1762), a whole species of secular literature about children came into being, something which, in the past, had only existed in spots, as among the Greeks or in the episode of Mamilius in Shakespeare (A Winter's Tale). After the long nightmare of the French Revolution and the Napoleonic Wars, there was an actual springtide of hope and aspiration for European humanity. Poets of liberty arose—Shelley,

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* Mahaffy, *op. cit.*, p. 168.

Byron, Wordsworth, Landor, Hugo, Swinburne—champions of liberty and liberal legislation, such as Stuart Mill, Beaconsfield, Peel, Gladstone, Louis Blanc, Armand Carrel, Mazzini, Kossuth—humanitarian novelists like Dickens, Charles Reade, Victor Hugo—everywhere, in fact, there was an upspringing of liberal sentiment and philanthropy. English labor legislation began in 1802 (Peel Act), child legislation in 1836. Victor Hugo's great prose epic on the miseries of the poor (*Les Misérables*) was completed in 1862. Three years later, the *loi Roussel* was passed (1865). Charles Dickens, whom Swinburne called "the greatest Englishman of his time," fought with tongue and pen for the rights of the child, to whom he devoted some of the choicest fantasies of his genius. Poetry about children culminated in such exquisite things as Victor Hugo's *L'art d'être grand-père*, Longfellow's *Delia* and *The Children's Hour*, Stevenson's *A Child's Garden of Verses*, and the dainty lyrics of Swinburne and Sir Rabindranath Tagore. The disabilities cast upon girls by female infanticide in the past have completely disappeared. The process of deification began with Dante's Beatrice. Goethe's Mignon, Dicken's Little Nell, Dr. John Brown's Marjorie Fleming, Victor Hugo's Cosette, linger in the memory as figures of essentially modern interest. The systematic spoiling of young women by cheap flattery and ill-considered adulation is a specific feature of recent life and of the more ephemeral sort of modern literature. The net-result has been to make the young person, in Boyesen's phrase, "a perfect little monster of human selfishness." The feeling of Andrea del Sarto, Correggio, Rubens and Vandyke about the child in painting has been revived in many modern canvasses. In music, such preludings as Haydn's *Toy Symphony*, Schumann's *Scenes of Childhood* and his *Album for the Young* were followed by endless imitations, even at the hands of Brahms, Tschaikowsky and Debussy. Schumann's "Requiem for Mignon" and Louis Ehlert's "Requiem for a Child" are examples of another *genre*. The child in folk-song is a modern revival. The cradle songs of Chopin, Grieg, Wagner and Brahms are full of poetic charm. The "Adventures in a Perambulator," an orchestral suite by John Alden Carpenter, of Chicago, is a most delightful specimen of American music. Richard Strauss has apotheosized the baby as the tyrant of the household in his "*Symphonia Domestica*," the squallings of the infant being rendered *fortissimo* by the full orchestra. To the old folk-tales of the past have been added Grimm, Hans Andersen and hosts of later things. Every Christmas brings out a flood of books, pictures and music about children. Thus the glorification of the child in modern life has been due to the artists, the poets, the writers, the musicians, rather than to the statists, philanthropists and legislators.

Let us now consider the **status of the child in folk-medicine.** From the moment of conception, the infant, born or unborn, is thought to be exposed to a swarm of evil demons who may inflict a disease or malformation upon the helpless child, or substitute one of their own brood for it as a changeling, and thus make it a cretin or other monster (Ploss).* Witches and sorcerers may cast spells upon it or it may be subjected to the influence of the evil eye. Against these malign influences, all sorts of charms, amulets, talismans, incantations and spells are employed, the varied ritual of which makes up a large part of ethnic folklore. An equally complex and variegated ritual presides over the bathing, washing, swaddling, cradling, nursing, wet-nursing, artificial feeding, naming, baptism and carrying of the newborn infant among different peoples. These practices have been described in detail by Ploss (*Das Kind*).† The care of the sick child in the savage and semi-civilized state‡ forms another large chapter of anthropology. Apart from actual infanticide, the high mortality of infants and children among savage and primitive peoples is due mainly to one set of causes: Total ignorance of the proper care and hygiene of children, mental inability to evolve a proper hygienic scheme, with the natural indifference resulting from this state of mind. Primitive pathology invariably assigns demons, magicians, witches and angered gods as the efficient causes of disease, adult or infantile. Primitive therapy professes to dispose of these by prayers, incantations, charms and other manœuvres of the medicine man. In Imeretia (Caucasus), the mother of a sick child walks thrice around its bed and then prays upon her knees that the malignant *batoneti* will take her soul rather than her child's; prayers are offered by the father, and oxen, fowls or pigs are allowed to wander away as an offering to the demon. In the lower Congo region, a family consultation is held over the sick child, and a magician is summoned, whose diagnosis is inevitably "witchcraft." Among the Wahehe (East Africa), if a sick child does not get well, a soothsayer (*mlagasi*) is summoned, who, after learning the probable amount of his fee, moves an inverted mortar over the top of a stool, repeating a litany of diseases the while; the mortar stops when he achieves his diagnosis, which is further confirmed by revolving a horn about a stick, until it stops at the name of the presumable disease (Ploss). In England, Ireland, France and Germany, sick or rachitic children are passed through clefts or arching roots of trees, holes in large stones or other rocky formations, bell-ropes, ladders, etc. This is also a remedy for infantile hernia. Infantile convulsions ("*Fraisen*") are suppressed in Silesia by placing the mother's engagement ring or her bridal crown in the child's bed; in Bohemia, by administering milk mixed with soot from a candle-snuffer, or three cinders from the hearth, in the name of the Holy Trinity; in Moravia by casting a garment, snatched from the child's body, into a rapidly flowing stream; in Upper Austria by winding yarn, spun by a girl of seven, about the infant's neck. In

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* H. Ploss, Das Kind im Brauch und Sitte der Völker, 3 Aufl. Leipzig, i, (1911), p. 100.

† *Ibid.*, pp. 211–514, *passim.*

‡ The details in this section are taken mainly from the chapter "Das kranke Kind" in Ploss, *op. cit.*, 515–547. The subject is even more elaborately treated in Hovorka and Kronfeld: Vergleichende Volksmedizin, Stuttgart, 1909, ii, pp. 632–718.

Lower Austria, talismanic necklaces are employed; in Moravia and Styria, little helmet-shaped caps (*Fraisenhauben*) decorated with religious emblems, are worn; in Styria, again, a "convulsion-clock" (*Fraisenuhr*) is wound up and chimes at intervals during the attack.* Among English folk-remedies for whooping cough in children are passing the child underneath animals or bushes, carrying it through a cloud of smoke, placing a live frog or the head of a trout in the child's mouth, giving it a soup cooked over a stream flowing from north to south, passing a tarred bandage around its neck, administering a roasted mouse or owl broth, or holding a decrepid spider over the patient's head while repeating the charm:

"Spider, as you waste away,
Whooping cough no longer stay."

Malaria, as we read in "Evangeline," was "cured by wearing a spider hung round one's neck in a nutshell." In Scotland, a consumptive child is passed through a wreath of woodbine, and on Mayday, sick children are taken to healing wells. In the Transvaal, Franks saw three sick children, painted green all over, with the exception of their faces, and all these succumbed to arsenic poisoning. The same observer saw a Boer mother give successively to a two year old child Hoffmann's drops, an opiate, a red powder containing tartar emetic, Jamaica ginger and Holland drops. Woodroffe prescribed for a Boer child, whose mother subsequently obtained another prescription from a second physician, in order to experiment with the two in succession. Cassia fistula and rhubarb are favorite infantile purgatives among primitive peoples. Clysters and vegetable emetics are frequently employed. The Zulus in Natal give the newborn a perfunctory clyster of the juice expressed from the roots of the "amasabele" (*Euphorbia pugniformis*), in warm milk, in order to "purify the stomach." As a vermifuge, they employ a decoction of "incamu" (*Othonna natalensis*). The **use of opiates** to quiet fretful infants is deplorably wide-spread among all peoples, savage, peasant or civilized. The exhibition of opium to stop a child's crying is as old as the Ebers Papyrus.† Syrups and decoctions of poppies or hyoscyamus are of common use for this purpose in the Orient, whence the pernicious custom spread among the Persians, Tartars and Armenians, and thence to Russia, the Germanic countries and the British Isles. Even in the forms known to city dwellers, as paregoric, soothing syrup, "Godfrey's Cordial," "Mother's Blessing," "Dalby's Carminative," etc., the exhibition of opium in teething and night-fears of infants is an almost universal folk-remedy,‡ which has led some anthropologists to derive it primarily from folk-intuition. To explain the genesis of intuitive folk-therapy, Hovorka postulates certain "laws of congruence," in virtue of which primitive man everywhere sought identical remedies instinctively for certain affections,* but the real explanation of "doping" the children is that the practice originated in the East, where the poppy abounded in nature. In therapeutics, however, the folk-mind has a notable tendency to favor the doctrine of "like cures like," *e.g.*, a drowsy syrup for a disorder of sleep. But, as a rule, the primitive doctor, vaguely sensing the fact that time and nature are often the best remedies, seeks every excuse for temporizing, and, in his attempt to "explain" the phenomena of disease, is easily led away into animism and mysticism.

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* Hovorka and Kronfeld, Vergleichende Volksmedizin, Stuttgart (1909), ii, pp. 674–684, *passim*.

† See H. E. L. Lüring, "Die über die medicinischen Kenntnisse der alten Aegypter berichtenden Papyri." Strassburg dissertation. Leipzig (1888), p. 45.

‡ Ploss, *op. cit.*, pp. 531–533.

The bad and sometimes fatal effects of the exhibition of opium in infants were early noted by Walter Harris (1689) and were described in impressive manner by the English physiologist Marshall Hall (1885),† but his essay did little to check this abuse. Some English druggists are said to have purchased over 200 pounds of opium annually for this purpose, and in one district an annual dispensation of 100 grains per caput was estimated.‡

We are now in position to review the history of pediatrics in the written and printed texts, beginning with the hieroglyphic and cuneiform inscriptions.

EGYPT

In Ancient Egypt, the military and priestly castes existed as beings set apart for sacred functions: The lot of the toilers, those in whom the hand was subdued to the material it worked in, was as that of the craftsmen in Ecclesiastes: "They shall not be sought for in public counsel, nor sit high in the congregation; they shall not sit on the judges' seat." Neuburger cites an early Egyptian sentence about the working classes: "The child is procreated only to be torn from its mother's arms—if he arrives at manhood, his bones are broken as those of an ass."§ But the civilization of Egypt was of matriarchal type. The mother-goddesses Hathor, Mut, and Neith, deifying the creative power of nature, the nature goddesses Anquet (fructifying power of Nile), Bast (fructifying heat of the Sun), the pregnant cow-goddess Mehurt (female creative principle), Nephthys (decay, death and immobility), Nut (Night), Satet (inundation of the Nile), Sekhet (destructive heat of the Sun), Tefnut (rain), also the birth goddesses Nekhebet and Taurt, who presided over obstetric functions, Meskhenit, who appeared at the child's cradle and Rannut who presided over the harvests, maternity and nursing, all bespeak the strength of the female and maternal element in the Egyptian pantheon. Isis the sister-spouse of Osiris, the type of the faithful wife and mother, is usually represented in the act of suckling Osiris. Women in the mural decorations and figurines are nearly always of comely, attractive semblance, and in the family groups there is every sign of affection. In the earlier Egyptian civilization, there are some evidences of human sacrifice, but no indications of "infanticide," or maltreatment of children. Egypt was a land of plenty, and children were well taken care of. Aristotle says explicitly that the Egyptian women bore many children and that all children born into life were well brought up. Diodorus Siculus (1st century, B.C.) records (I, 20) that the children of ancient Egypt were clothed and reared at a very trifling expense. He says of the ancient Egyptians that those who killed their children were not executed themselves, but were condemned to hug their dead offspring continually in their arms for three days and three nights, in order to experience their full deserts of horror and remorse (I, 6).* The items listed in Sudhoff's Catalogue of the Historical Section of the Dresden Hygienic Exposition (1911) suggest a highly specialized civilization with plenty of creature comforts.

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* O. von Hovorka, Mitt. d. anthrop. Gesellsch. in Wien, 1915, xlv, pp. 125–136.

† Hall, "Practical Observations and Suggestions in Medicine." London (1845), pp. 174–176.

‡ Ploss, *op. cit.*, p. 532.

§ Neuburger, Geschichte der Medizin, Stuttgart, i, (1906), p. 52.

The mural reliefs and frescoes from the temples show the threshing of grain (items 1101–8), the kneading of dough (1109–11), the harvesting of figs (1118), a market scene of the Old Empire, with stands for fish, vegetables, a fish-pond with ducks, in a rich park (1131), milking a cow (1162), a child suckled directly from the udders of the cow-goddess Hathor (1163), vintage and wine-making (1173–77), brewing beer (1178–84), a dining table set for the dead (1193), beds and wooden head-rests (1225–35), vanity cases (1307), manicures (1310), cosmetics (1311–12), combs (1323–5), mirrors (1327–9), razors (1331–48), a woman prinking herself with cosmetics before a mirror (1354), bathing in common (1397), the complaint of a Greek woman to Ptolemy (220 B.C.) that she had been parboiled in her bath by a careless attendant (1410), the *accouchement* of a queen on an obstetric chair, attended by four midwives (1423), Isis suckling and dandling Horus (1425–31), modes of carrying children (1432–38), dolls and balls of 600 B.C. (1439), children's games (1440–42), dancing (1443–45), statues of physicians (1496–99), amulets and scarabs (1502–14); Horus as averter of a pathogenic worm (1515); apotropaic reliefs of the child Horus against vermin (1516, 1518, 1523); a court official with a fly-flap (1524); aboriginal Egyptian rites for cult-cleanliness (1525); the interment of a child's corpse in a bed (1534), coffins, burial-rites, sarcophagi and mummies (1530–1632), and pathological preparations from diseased mummies (1630–1728).†

At birth, the Egyptian infant was not constricted in swaddling clothes but allowed to run about naked or carried about in loose, soft wrappings. After weaning, its diet was cow's milk only, later vegetable foods and water. It led a wholesome healthy existence in the open air, completely naked up to five, barefoot up to ten, playing with hoops, balls and dolls before taking up the "three R's" in school (Neuburger).‡ Ritual circumcision was performed upon boys of the priestly and warrior castes with a flint knife. Self abuse is named as a vice in the Book of the Dead.

Of Egyptian medicine, Homer says (Odyssey IV, 220–223): "There the fruitful earth brings forth many drugs, many excellent when mingled, and many fatal;

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* Diodorus Siculus Historical Library, transl. by Booth: Vol, 1, par. 6, p. 79. Cited by Payne.

† "Internationale Hygiene-Ausstellung." Dresden (1911). "Historische Abteilung," 2. Aufl. Dresden (1911), pp. 33–54, *passim.*

‡ Neuburger, *op. cit.*, p. 52.

there every physician is skilled above all men; for truly they are of the race of Pæon."

Medicine in Egypt, as Herodotus tells us, was specialized to the extent of having a doctor for every disease. A set line of treatment was prescribed and if the patient died from any deviation from standardized practice, the physician was put to death; although in the time of Aristotle, a change of therapy was permissible after the fourth day, if the patient did not improve.

The principal sources of Egyptian medicine are, in order of antiquity, the badly preserved London Papyrus, edited and translated by Walter Wreszinski (1910), the Westcar (Lesser Berlin) papyrus, translated by Adolf Erman (1890), the Brugsch (Greater Berlin) papyrus, translated by Wreszinski (1909), the Papyrus Ebers, translated by H. Joachim (1890), the Hearst (Philadelphia) papyrus, containing about one half the Papyrus Ebers and the Kahun papyri of the Petrie Collection, translated by F. L. Griffiths (1893). Of principal interest for Egyptian pediatric lore are the Lesser Berlin and the Ebers papyri.

The Lesser Berlin Papyrus, or Papyrus of the Mother and Child (16th Century B.C.) is, for the most part, made up of wonder tales and magic charms. It contains only three prescriptions. Holmes cites a charm to be recited over a string of three beads (lapis lazuli, jasper, malachite) to be hung about the neck of the newborn. Part of another reads:

> "The voice of the Re calls for the *Wpt,* because the stomach of this infant whom Isis has borne, is sick."*

The Papyrus Ebers (1550 B.C.), a beautiful document in hieratic script, the text in black, the rubrics in red, is an *édition de luxe*, probably prepared for some great temple. The fact that it is written in several dialects indicates that it is an encyclopėdia or compilation. In its entirety, it was, no doubt, a summary of the medical and surgical therapeutics then known, like the summations (*summa medicinæ*) made in the Middle Ages or our modern "Systems of Medicine." It consists of some 50 sections in 108 columns, giving prescriptions for various diseases and classes of diseases. Only in the surgical section is there any indication of diagnosis. The tiny pediatric section is mainly prognostic. It reads:

> "To get a supply of milk in a woman's breast for suckling a child: Warm the bones of a χra-fish (swordfish, Brugsch) in oil and rub her back with it. Or:
> Let the woman sit cross-legged and eat fragrant bread of soured *durra*, while rubbing the parts with the poppy plant."
> Prognosis for a child on the day of its birth:
> If it cries *nee*, it will live; if it cries *bá* it will die.
> Another prognostication:
> If it wails loudly, it will die; if it drops its face downward, it will die immediately."†

Among the diseases likely to affect children, which are prescribed for in the Ebers Papyrus, we find those due to the *heft*-worm (*Ascaris lumbricoides*), the *pend*-worm (*Tænia mediocanellata*), diseases of the

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* Bayard Holmes and P. G. Kitterman, "Medicine in Ancient Egypt." Cincinnati (1914), p. 13.

† H. Joachim, "Papyros Ebers." Berlin (1890), pp. 178–179.

Ro-ab (epigastric region), headache; ascites and urinary disorders; physical disability; diseases of the eye, the scalp, the skin, the teeth and ears; coryza and ozæna; animal parasites, fleas, lice and pruritus; abscesses and tumors. Purgatives and vermifuges abound, as also prescriptions for diarrhœa and obstinate vomiting. The following recipes are specified for retention of urine in children:

"An old book, cooked in oil, is smeared over the body, in order to produce urination in the child."

"Another prescription to regulate urination:

Straw of the nebat plant	⅛
Dates	¼
The stalk of the χas-it plant	¼
Honey	⅚
Berries of the uan-tree	¼
Water	1 dená

Strain and administer through four days running."

"Another prescription to regulate urination in a child: Bring blossoms of the nebat plant together with sweet beet in a cool flask for a girl to drink; but give it to a boy in a pitcher of hennu (0.465 litre) capacity."

"What one should do for a child that suffers from urination: χent corn warmed in a pill; if it is an older child let it take this with its nourishment; but if it is an infant, let it be given in the breast milk, the nurse warming it in her mouth and spurting it into the child's mouth."

"A remedy for incontinence of urine.

Juniper berries	1
Cyprus	1
Beer	1 hennu measure."*

An opiate is exhibited for the crying of a child.

"Capsules of the poppy-plant (?); excrement of wasps on the wall; rub together; strain and administer for four days running; it will stop immediately; as for crying, it is the child that cries."†

These prescriptions show that there was already differentiation as to drugging and dosage in treating the diseases of children and adults. There were even separate hieroglyphs for the infant and the child (Lüring).

Among the diseases from intestinal worms, there are many remedies for the tropical anemia variously known in the Ebers Papyrus as the uha disease (chronic constipation and meteorism), the uχedu disease (painful swelling of the body), and "the god-sent deadly āaā disease." It is probable that these were different phases of hookworm infection (*chlorosis Aegyptica*) or other parasitic anemias. In the opinion of Joachim, the āaā disease was ankylostomiasis, since precordial distress and palpitation of the heart is specified in the Papyrus (Lutz), and the disease was found by Pruner Bey, Bilharz and Griesinger, to be still prevalent in Egypt.‡ Edwin Pfister, however, maintains that the āaā disease was bilharziosis, since its determinative hieroglyph was a phallus (bloody urine).[*] There is a special prescription for the *sa*-worm or *Filaria medinensis*.[†] Granular conjunctivitis (Egyptian ophthalmia), the contagious nature of which was first observed by Baron Larrey during Napoleon's Egyptian campaign (1802), is specified in the Ebers Papyrus as excessive lachrymation or "granulation" or "when too much water flows from the eye."[‡] Corneal opacity, albugo, clouding of the lens and strabismus are prescribed for,[§] and there are innumerable salves and collyria. The sections in the Ebers Papyrus on fatty tumors, suppuration and ulcers show definitely that surgical intervention obtained in these conditions ("treat it with the knife").[‖] Toothache is attributed to the presence of the uχedu worm.[¶] The researches of Elliot Smith and Wood Jones on pathological findings in Egyptian mummies from the Archæological Survey of Nubia (1907), show that there was no caries in the milk dentition of children of the Pre-Dynastic period. The luxurious habits of the New Empire produced deposits of tartar with caries and abscess formation, spreading to the alveoli. This condition in the mummies shows that the Egyptians had no dentistry, the alleged gold-filling of teeth being simply gilding, as part of the mortuary ritual. There is one disease, specified in the Papyrus Ebers as "hardening in the limbs" (and by the prescriptions "to make the joints limber"),[**] which is found in mummies of all historic periods, namely osteoarthritis deformans, and while this affected adults only, it began to attack them even in the third decade of life. An apparent case of infantile paralysis (poliomyelitis) is exhibited in a stele of the Eighteenth Dynasty in the Carlsberg Glyptothek, Copenhagen.[††] Henri Meige describes a bronze statuette of a hump-backed Egyptian boy from the Museum at Bulaq, the deformities suggesting rickets or spondylitis deformans.[‡‡] The innumerable figurines of the dwarf-gods Bes and Phthah are all achondroplasic (Charcot).[§§] In the Alexandrian period, Egyptian medicine became Greek in type. In Sudhoff's study of the Oxyrhynchus and other Greek papyri of the period, considerable light is thrown upon the methods of wet-nursing and circumcision. The Hellenized ladies of the Ptolemaic period seldom nursed their own children. Definite contracts were made with slave-women, who stipulated to nourish the child on milk up to its third year (γαλακτοτροφια) for a definite sum and their living. During the first six months the nurse was to give the infant her own breast; during the remaining eighteen months, it was nourished artificially on cow's milk. There was a regular daily delivery of "the best cow's milk" in a pitcher of 18 cotyles capacity; and unpunctual delivery was severely punished, but on legal, not on hygienic grounds.* The wet-nursing contracts called for "pure unadulterated milk," *i.e.*, that the nurse should not spoil her breast-milk by a faulty diet. A child's sucking bottle of the 2nd century, from Tebtunis, is in the Museum of Cairo (reproduced by Sudhoff). It is an ovoid flask of polished burnt clay, with a cylindrical neck and a nipple-shaped mouth-piece at the side.† The slaves who became gladiators, wet-nurses, harlots, etc., were recruited from the abandoned infants flung upon dung-heaps by heartless parents. If found by benevolent persons, they were usually wet-nursed and brought up. If not they were devoured by dogs and wild animals. Baby farming was practiced, and attended by the same cruelties that moderns know of.‡

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* Joachim: *op. cit.*, 65, 67–68.

† *Ibid*; p. 169.

‡ *Ibid.*, pp. xiv–xvii.

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[*] Pfister, Arch. f. Gesch. d. Med., Leipzig, 1912–13, vi, 12–20.

[†] Joachim: *op. cit.*, p. 134.

[‡] *Ibid.*, pp. 81, 83; 86.

[§] *Ibid.*, pp. 82; 85–87.

[‖] Joachim: *op. cit.*, pp. 191–192.

[¶] *Ibid.*, p. 161.

[**] *Ibid.*, pp. 130–134; 137–151.

[††] O. Hamburger: Bull. Soc. franc. d'hist. de méd., Paris, 1911, x, pp. 407–412.

[‡‡] Meige: Trav. de neurol. chir. (Chipault), Paris, 1897, ii, pp. 101–105.

[§§] Charcot: "Les difformes et les malades dans l'art." Paris (1889), pp. 12–26.

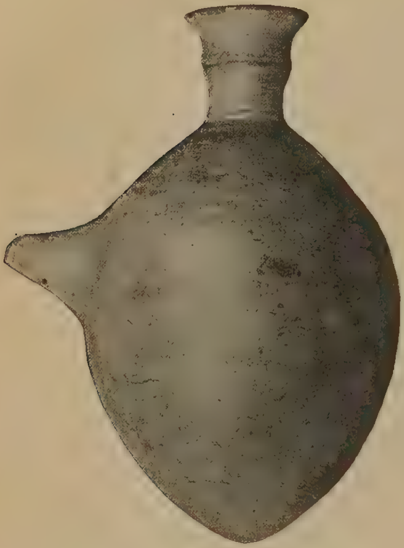

FIG. 1.—Egyptian nursing-flask of the Alexandrian period, with nipple (Cairo Museum). (From Sudhoff's Studien zur Geschichte der Medizin, Leipzig, 1909, Heft. 5–6, Pl. III.)

SUMER AND ACCAD

(Assyro-Babylonian Civilization [2800 B.C.–3310 B.C.])

The fertile plain between the Euphrates and the Tigris, "the land between the rivers," erstwhile Babylonia, later Mesopotamia, was originally divided between two primeval races. At the North was Accad, dominated by a Semitic race; at the South lay the Biblical "plain of Shinar" or Sumer, the inhabitants of which were non-Semitic. Whether the Sumerian culture preceded the Accadian or not is a matter of dispute, but it is known that the Sumerian characters (ideograms) contained Semitic elements, and it is probable that there was the usual interaction between the two cultures.

Secular History.§—The tug of war between the Sumerian and Accadian peoples occupied the earlier historical period, a period of massive architecture, sun and moon gods, ornamented vases and other votive offerings to such gods, and illustrated clay seal cylinders with cuneiform characters, designed to be rolled over flat clay tablets as personal signatures to contracts and other business documents. Under Sargon and his son Naram-Sin, the Accadians first began to dominate this vast agricultural region; but about 2300 B.C., the Sumerians regained their ancient sway and their rulers were thenceforth known as "kings of Sumer and Accad." At the North of Accad, Hittite influences became predominant about 2100 B.C. A Hittite ruler occupied the throne of Babylon (Accadia) about 1800 B.C., and from a presumable fusion of Hittite and Amorite elements, the northernmost kingdom of Assyria arose. About 2000 B.C., the Sumerian power began to wane and the Semites centred their independent kingdom in the city of Babylon. With the accession of Hammurabi as "king of Babylon" (1958–1916 B.C.), the Accadian kingdom became known as the Babylonian Empire. The successive blows dealt by the warlike Assyrian kings Tiglath Pileser I (*circa* 1130–1100 B.C.), Ashurnasirpal (884–860 B.C.), Sennacherib (705–681 B.C.) and Esarhaddon (680–669 B.C.) eventually reduced Babylon to subjection. Babylon was destroyed by Sennacherib in 689 B.C., but after the brilliant reign of Ashurbanipal or Sardanapalus (668–626 B.C.), the Assyrian yoke was broken by Northern invaders at the fall of Nineveh (606 B.C.). The new Babylonian empire came under Chaldean influences under Nabopolassar (625–604 B.C.) and his, son Nebuchadnezzar (604–561 B.C.) Cyrus took Babylon in 539 B.C. but the Persian power was overthrown by Alexander the Great (331 B.C.). Thus the civilization called Assyro-Babylonian was influenced successively by the domination of five distinct racial and cultural strains, the Sumerian, Accadian (Semitic), Assyrian (Hittite), Chaldean and Persian.

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* K. Sudhoff: Aerztliches aus griechischen Papyrus-Urkunden (Stud. z. Gesch. d. Med., Heft 5–6)." Leipzig 1909, pp. 150–157.

† *Ibid.*, plate 3.

‡ *Ibid.*, pp 1. 58–159.

§ M. Jastrow: "Aspects of Religious Belief and Practice in Babylonia and Assyria." New York, 1911.

In the older Sumerian pantheon, the sun, the moon, fertility in plants, animals and man, storm-power and water-power were deified and worshipped in various places as gods. In the period of Babylonian ascendancy, the storm-gods Enlil and Ninib give place to two new deities, Marduk, the sun- and water-god, the source of wisdom, and Nergal, representing the sun's destructive power, the god of pestilence, famine, war and death. Ninib was the ancient god of healing, and with him was always associated his consort Gula.*

But in the period of Assyrian domination, the mother-goddess Ishtar, as the consort of Ashur, a great god of the Assyrian pantheon, becomes the central figure of the Assyro-Babylonian culture. The ascendancy of Ishtar as mother-goddess is an index of the strong matriarchal element which prevailed in the Assyro-Babylonian period, an influence which, as Morris Jastrow points out, is characteristic of all ancient Semitic civilizations. Ishtar, identical with the planet Venus in Babylonian astrology, the Ashtoreth of the Canaanites, the Astarte of the Phœnicians, may be equated with Rhea and Hathor, the mother-goddesses of Crete and Egypt, or with the *alma genetrix* of Rome. Ishtar represents the generative principle in nature, "the *mater magna* who gives birth to everything that has life." She presides over fertility in vegetation, animals, and man, is simultaneously the goddess of love, of war and storms, the protectress of flocks and the universal nurse of mankind. In the votive figurines which have been found, she is represented as a nude figure of comely aspect, usually suckling a child supported on her left arm.

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* For a full account of the Babylonian mythology, see M. Jastrow: "Aspects of Religious Belief and Practice in Babylonia and Assyria," New York (1911).

In a civilization with undoubted matriarchal tendencies, there is a strong presumption that children will be not unkindly treated. Babylonian alabaster dolls exist, and are remarkable for beauty. From the items listed in the Assyro-Babylonian group in Sudhoff's Catalogue of the Dresden Hygienic Exhibit (Historical Section), we get some idea of the degree of civilization of these remarkable peoples.

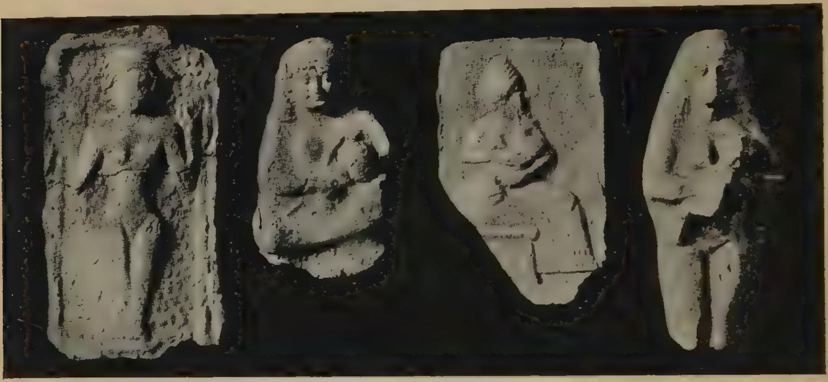

Fig. 2.—Terra-cotta reliefs and figurines of Ishtar (Babylonian mother-goddess).

Reliefs and bronzes show King Ashurbanipal and his queen dining in the open under a grape-arbor (621); the interior of a Babylonian tent, in which beds are made, flies are driven away, and tables with low seats are set for dining (621); King Ashurbanipal under a parasol held by eunuchs (731); Sennacherib under a parasol in a deer-park, with a coach drawn by men (732); boxing to the accompaniment of drums and castanets (742); riding and hunting scenes (742–3); swimming with bladders (745–6); the transportation of a huge stone colossus in a vehicle drawn by men (758); business archives and contracts in cuneiform characters on clay tablets (788–803), and the slipper-shaped coffins, capsule tombs and fan-shaped sarcophagi for disposal of the dead (807–845). Among the medical and pediatric items are the duties of a nurse, from the Code Hammurabi (611); the remarkable Babylonian wells, drainage pipes and latrines (636–648); prescriptions for cult-cleanliness (650); rites for the purification of a city contaminated by excreta of sick people (650); children's clothing in the time of Ashurbanipal, from a relief at Nineveh (675); a woman suckling her child, from a Hittite relief (705); fly-flaps (716–18); laws against the injury of pregnant women (736); physicians' seals (762–3); cuneiform prescriptions for a skin disease (765); models of the liver (766–7); amulets (779–80); vultures as scavengers of the battle-field, with collection of the fallen dead in a common pit (806), and children's coffins (816–17).*

In the **Code of Hammurabi** (2250 B.C.) we find the strongest evidence of equitable dealing with women and children in Babylon. The Code-Hammurabi is perhaps the oldest codification of laws known. In simplicity and directness of statement it is a model of what a law-book should be. There is no pettifogging or obscuration; everything is expressed with such unmistakable clearness that it could be understood even by the unlettered and ignorant. There are some harsh rigors and the *lex talionis* ("an eye for an eye, a tooth for a tooth") is prominent, but with inexerable fairness.

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* Sudhoff: Dresden Catalogue (1911), pp. 20–28.

Adultery, seduction, rape and incest were punishable by death. The loss of any part of the body in an assault was punished by the loss of the same part in the offender. If a son denied his parents, his tongue was excised (192); if he hated them, he lost an eye (193); if he struck his father, his fingers were cut off (195); if a nurse allowed a suckling to die on her hands and substituted another, her breast was amputated (194); if a man struck a pregnant woman producing miscarriage, he had to pay the expenses to ten silver shekels (209); if she died, the offender's daughter was put to death (210). A man in debt might sell his wife, son or daughter or bind them out for service for three years, after which they were free (117). If a man put away a wife or concubine, he must make good her dowry; if she had children, their support was assured (137–8). If a wife died, her dowry went to her children (162); if she had a successor, the children of the two marriages inherited the dowries of their respective mothers and an equal share of their father's effects (167). Property deeded to a widow by her husband could not be sold but went to her children after her death (171). The children of a slave (father or mother) were free, if the other parent was free (171, 175). If a woman married twice, she inherited a son's full share of his estate (180). An adopted child could not be claimed by anyone (185). If an adopted son were not fairly treated, he might return to his father's house (189–190); an adopted child could not be disinherited by its foster parent, unless he received one third of a son's portion in advance (191).*

Thus the attitude of Babylon toward women and children was that of a nation of lawgivers. They were severely punished for infractions of the Code, but otherwise treated with absolute, unswerving justice. Long before Hammurabi, King Urukagina did much for the maintenance of the family by abolishing the briberies connected with the divorce laws. Mothers were pensioned that their children might be educated. Women could hold property and maintain their property rights. The signature of the queen was added to that of the king in all public documents. In a statistical table of the time giving the provisions made for women attached to the temple of Bau, 552 women, 132 girls and 97 boys are enumerated. The preponderance of the female element shows that there was no prejudice against girls nor any female infanticide. The Sumerian family seldom included more than four infants. The Assyrian Doomsday Book (Liber Censualis) of the 7th Century B.C. enumerates 68 husbands with 94 wives, 74 sons and 26 daughters, but in some of the families, there were three daughters to one son. Most of the families were limited to one or two sons, which suggests birth control, but not female infanticide.† The modesty of Babylonian art has been noted by Ward. In the items of female costume listed by Sudhoff in his Dresden Catalogue (652–705), there is no evidence of deliberate exposure of the breasts, as in Egypt, primordial Crete or even Hellas. Women were well covered by the Sumerian mantles and Semitic plaids, which were wrapped about the body in terrace-fashion. The comeliness of the Babylonian female figurines and dolls suggests the kind of lively appreciation which leads women to conserve their beauty.

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* R. F. Harper: "The Code of Hammurabi," Chicago (1904), *passim.*

† G. K. Payne: "The Child," New York (1916), pp. 95–105.

Herodotus describes the Babylonians as having no physicians, the sick being placed in the market place to receive the advice of every passer-by. But the rigorous regulation of medical fees in the Code Hammurabi suggests an advanced stage of specialization in medical practice, even in remote antiquity (2250 B.C.). The essential features of Babylonian medicine were the attribution of each disease to a special demon; diagnosis by inspection; prognosis by divination, liver-inspection (hepatoscopy), birth omens, disease omens and astrological portents; therapy by exorcision and exhibition of herbal remedies; prophylaxis by incantation (Jastrow).* In the Sudhoff Catalogue, there are listed bronze figurations of Utukku, the demon of the throat disease, possibly diphtheria (775*a*), and exorcisms against Labartu, the demon who threatens the lying-in woman and her new-born child (776–783). In a bronze tablet, described by Morris Jastrow, there are seven demons of disease, terrible in aspect, and Labartu appears as a horrible figure "holding a serpent in each hand, with swine sucking at her breasts." Exorcisers, clad in the robes of the god Ea, stand at either end of the sick bed, sprinkling the patient with some compound to drive the particular demon away.† The terra cotta models of sheeps' livers for divination, some of them 3,000 years old, divided off into squares, with prophetic inscriptions, are better examples of anatomical illustration than the five-lobed livers of the medieval anatomists. The liver was the source of blood and the seat of the soul, and to see into the soul gave insight into the mind of the god, when enterprises of moment were contemplated.

The Babylonian **birth omens,** of which the study of physiognomy and phrenology were by-products (Jastrow), were connected with the primitive awe for "the mysterious phenomenon of a new life issuing from another." Babylonian pediatrics was, in fact, mainly concerned with this variety of prognostication. Any abnormity or monstrosity in an infant or an animal at birth was prognostic of its future welfare. "An abnormally large organ pointed to extension, to power, to success; an abnormally small one to weakness, disease and failure" (Jastrow). This is in agreement with Adler's psychological theory of "organ inferiority" as a cause of mental depression and discouragement. Abnormality or hypertrophy on the right side concerned the patient, on the left side his enemy. The Babylonian birth omens have been studied by Boissier (1894), Jastrow (1913) and Dennefeld (1914). A few specimens, from Jastrow's study are subjoined:

> "If a woman gives birth to twins in an abnormal condition, the land will perish, the house of the man will be destroyed.
>
> "If a woman gives birth to two girls, the house will be destroyed.
>
> "If a woman gives birth and the right ear is small, the house of the man will be destroyed; if the left ear is small, the house of the man will be enlarged; if both ears are small, the house of the man will be overthrown.
>
> "If a woman gives birth and there are six toes on the right and on the left foot, the children will encounter misfortune.

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* M. Jastrow, Proc. Roy. Soc. Med., Lond., vii (1914), pp. 109–176, *passim.*
† *Ibid.*, p. 137.

"If a woman gives birth and the child has a lion's ear, a powerful king will rule the land.

"If a woman gives birth and the upper lip rides over the lower one (agnathy), he will attain favor."*

While these omens, as in the savage, suggest a motive for infanticide, yet it seems probable, given the Babylonian's regard for the inexorable and irrevocable in law and accomplished fact, that infanticide in itself was not regarded as releasing the land or the individual from the ineluctable fate contained in the specific omen.

There were also omens of the same kind connected with the interpretation of peculiarities in disease, or the symptoms of disease.

In the treatment of disease, a pain in a definite locality implied that a demon was *eating* that locality; a symptom like fever or headache implied that the part affected was "seized" by the demon. In the Middle Ages, this Babylonian concept of seizure or possession by demons (*sibtu*) was still applied to epilepsy (*bennu*). Epilepsy was then regarded as contagious and there were actual isolation hospitals for epileptics in the medieval period (Sudhoff). Babylonian therapy was of two kinds, that in which exorcism and incantations were secondary to the exhibition of remedies, and that in which the use of drugs was subordinated to magic rites (Jastrow). Over three hundred drugs were known and divided, Jastrow believes, into organic (*shammu*) and inorganic (*abnu*). Thus a cold in the stomach (gastritis) was treated by drinking a decoction of licorice and six other drug simples in wine, night and morning; the patient was then taken into a boat and incantations were pronounced over him. As alternatives, the white meat of pork was sucked, to coax the demon out, salt and water were taken with the food, a kneeling posture, to relax the muscles of the abdomen, was assumed, hot or cold water was poured over the body, to stimulate the circulation, and even postures and rolling were employed.† Nauseating remedies were sometimes given to disgust the demon. Dietetic schemes were followed in digestive disorders. Massage was known and employed. The principal diseases known were those of the liver or gall-bladder (jaundice), the eye, the heart, the stomach, also rheumatism, neuralgia, and the *mangu* disease, which was probably diphtheria.

Strongly suggestive of the *Consilia* of the Middle Ages are the following letters (cited by Jastrow) from the physician Arad-Nanâ to the King Assurbanipal on certain ailments of his little son.‡ In each, Ninib, the god of healing and his consort Gula are invoked.

"Arad Nanâ to the king My Lord, Thy servant Arad Nanâ. Hearty greetings to the king, My Lord. May Ninib and Gula grant happiness and health to the king My Lord.

Hearty greetings to the little chap whose eye causes him trouble. I put a bandage on his face. Yesterday, towards evening, I took off the bandage that had been applied, removing also the dressing below, and there was blood in the dressing as much as the point of a little finger. To whichever one of thy gods this is due, his command has surely been heeded.

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* M. Jastrow: "Babylonian-Assyrian Birth Omens and Their Cultural Significance," Giessen (1914), *passim*.

† Jastrow, Proc. Roy. Soc. Med. Sect. Hist. Med., Lond., vii (1914), pp. 131–133.

‡ *Ibid.*, pp. 147–149.

Hearty greetings. Let the king My Lord rest assured; in seven or eight days he will be well."

The second deals with epistaxis:

> "Hearty greetings to the king's son. The treatment which we prescribe for him is to be given every two-thirds of a double hour during the day.
>
> In regard to the bleeding of his nose about which the Rab-Mugi has reported to me that yesterday toward evening there was much bleeding, those dressings are not properly applied; they have been placed upon the alæ of the nose, obstructing the breathing, while at the same time the blood flows into the mouth. Let the nose be plugged up to the back so that air will be held off and the bleeding will cease. If it please the king I will come to look at it tomorrow. Meanwhile, may I hear good news."

It is plain that royal physicians in the reign of Sardanapalus (668–626 B.C.) were what they are today.

In **preventive medicine,** the Babylonians had an eye to the harmful effects of insects, worms and parasites. They made long lists of them on clay tablets (Sudhoff, item 804), and even classified them. A cylinder seal in Pierpont Morgan's collection bears the "Fly-Symbol" of Nergal, the Mesopotamian god of disease and death. "Swatting the fly" appears to have been a Babylonian institution. Sudhoff's Catalogue includes a fly-flap as part of the trousseau of a Mitanni princess (716); a Hittite relief of a servant by the dinner-table with a fly-fan (718), and a Persian relief of a fly-flap of the time of King Darius (730). That children of the better class were similarly protected there can be little doubt.

The medicine of ancient Persia was limited to casting out the demons of disease, herbal therapy and the Zoroastrian rites of purification and cult-cleanliness. In such a system, pediatrics never even attained the gerundive mood of being about to be.

INDIA

In ancient India, as we have seen, the warrior-gentleman predominated, the caste system was rigid, the status of women was low, abortion and infanticide were common.

In the earliest Sanskrit texts, medicine is entirely theurgic, made up of spells and incantations against the demons of disease. The Rig Veda (1500 B.C.) is the folk hymnal of the Aryans of Northwestern India at the time of their successive westward migrations. In this great folk-song, women enjoy an elevated position similar to that in the Homeric poems. Beautiful hymns were chanted in their praise. Husband and wife were on a footing of equality as "rulers of the household," and there is no evidence of the burning of widows. Beef and beer from the juice of the *soma* or moon-plant (*Asclepias acida*) were the foods of these hardy nomads. The hymns of the ninth book of the Rig Veda, which is taken up with the deification of the *soma* as "overlord of plants," are called *pavamani* or "purificational" because they were recited while the juice expressed from the plant was clarifying. That physicians were employed and paid for their services in the time of the Rig Veda is evidenced by Neuburger's citations to the effect that the physician hopes to get by his cures "horse, cattle and clothes;" also, "The waggoner desires wood, the doctor sickness, the priest libations."* The tenth book of the Rig Veda contains a larger number of verses dealing with superstitious practices. About 1,350 of these are also found in the Atharva Veda Samhita, which belongs to a much later period, and consists mainly of spells and incantations. Many of the *mantras* or sacred sayings of the Atharva Veda are medical in character. This text may therefore be taken as representative of the germinal Vedic period (1500–800 B.C.) when medicine and magic were synonymous.

Employing Whitney's translation† a few pediatric charms of the Atharva Veda will suffice to illustrate this phase of our subject:

For Welfare and Long Life of an Infant (ii, 13)

1. "Giving life-time, O Agni, choosing old age, ghee-fronted, ghee-backed, O Agni, having drunk the sweet pleasant ghee of the cow; do afterward defend this boy as a father his sons.

4. Come, stand on the stone; let they body become a stone; let all the gods make thy life-time a hundred autumns.

5. Thee here, of whom we take the garment to be first worn, let all the gods favor; thee here, growing with food growth, let many brothers be born after, as one well born."

Against Worms (v, 23)

2. "O Indra, lord of riches, smite thou the worms of this boy; smitten are all niggards by thy formidable spell.

3. What one creeps about his eyes, what one creeps about his nostrils, what one goes to the midst of his teeth—that worm we grind up.

5. The worms that are white-sided, that are black with white arms, and whatever ones are of all forms—those worms we grind up.

6. Up in the east the sun, seen of all, slayer of the unseen, slaying both those seen and unseen, and slaughtering all worms.

9. The three-headed, the three-humped, the variegated, the whitish worm—I crush the ribs of it; I hew at its head.

13. Both of all worms and of all she-worms I split the head with a stone, I burn the mouth with fire."

For Birth of Sons (vi, 11)

2. "In the male, indeed, grows the seed; that is poured along into the woman; that verily is the obtainment of a son; that Prājapati said.

3. Prājapati, Anumati, Sinivālī hath shaped; may he put elsewhere woman-birth; but may he put here a male."

To Guard a Pregnant Woman from Demons (viii, 6)

9. "Whoever makes this woman having a dead child, or a miscarriage, him, O herb, do thou make disappear.

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* Neuburger: "History of Medicine." Transl. by E. Playfair, London, i (1910), p. 45.

† W. D. Whitney: Atharva-Veda Samhita (Harvard Oriental Series, vols. vii–viii), Cambridge (1905), *passim.*

18. Whoever shall handle thy embryo, or shall make it born dead—let the brown one, with formidable bow, make him pierced to the heart.

AGAINST VARIOUS DISEASES (ix, 8)

1. "Headache, head-ailment, earache, anemia, every head disease of thine, do we expel out of thee by incantation.

21. Forth from they feet, knees, hips, buttocks, spine, nape, the pains from they head, the disease have I made disappear."

In the Brahministic period (800 B.C.–1000 B.C.), Indian medicine attained its height. Well-trained physicians, descended on the father's side from Brahmins, belonged to an exalted mixed caste. The center of medical training was the sacred city of Benares, the seat of Brahministic learning. Aryan medicine in this period is remarkable for the highest development of surgery in antiquity, for a highly elaborated vegetable materia medica and poison-lore, including the use of hyoscyamus and Cannabis indica as soporifics in surgery, and a definite recognition of such facts as the symptoms and sweetish urine of diabetes, the transmission of malarial fever by mosquito-bites and the relation between bubonic plague and rats.

The three basic texts of Brahminical medicine are the works of Susruta (2nd Century B.C.) Charaka (1st Century A.D.), and Vagbhata (7th Century A.D.). It is in Indian medicine that we encounter for the first time a reasoned, consistent body of pediatric doctrine. Taking the **Susruta Samhita** as the most representative scripture, we find a well-defined section on pediatrics in the chapter on pregnancy.* After severing the umbilical cord, the baby's face is sprayed with cold water, and it is allowed to lick an electuary of honey, clarified butter, gold-dust and the expressed juices of *Bráhmi* leaves and *Anantā* from the ring-finger of the feeder. The body of the infant is then anointed and bathed with infusions of certain barks, or with decoctions of certain leaves or drugs, or in water in which red-hot gold or silver bars have been immersed, according to the season or the physical condition of the child. Breast-feeding is postponed until the fourth day after birth. Prior to breast-feeding, the necessary evacuation of the meconium is attained by the simple device of giving a little honey, a procedure afterward standardized by Rufus and Soranus of Ephesus; its *raison d'être* was apparently that of the "sugar diarrhea" of Orgler, Allen, Talbot and other metabolists. On the first day, the baby is fed at morning, noon and evening with a child's handful of clarified butter and honey mixed with pulverized *Anantā* roots, sanctified by the recitation of *mantras.* On the second and third days, the diet is clarified butter prepared with the *Lakshaná* root. On the fourth day, the child is given its own handful of honey and clarified butter at morning and noon; in the evening, the mother squeezes off a quantity of her own milk and gives the child her breast. The infant is wrapped in silk, laid on a bed covered with a silken sheet, and fanned with the branches of certain trees. A thin pad, soaked in oil, is kept constantly on its head, and its body is fumigated with the fumes of mustard, or other drugs, to avert evil spirits. The same drugs are also tied around its head, neck, hands and feet, for this purpose, and the floor of the lying-in room is strewn with pounded sesamum, mustard and linseed. On the tenth day of its life, the rites of benediction are performed, and the child is named. A wet-nurse, when required, is selected from the matrons of the child's own caste. She shall be neither too young nor too old, too thin or too corpulent, of sound health and good character, "of an affectionate heart and *with all her children living*," nowise addicted to gambling, debauchery, day-sleeping, etc. The breasts should be neither pendulous nor contracted, the milk plentiful and of good quality. Upturned or unprominent nipples may deform the child's mouth; flabby, pendulous breasts may suffocate it. At nursing, on an auspicious day, the child, its head well-washed, is laid on the woman's lap, wrapped in clean, untorn linen, with its face to the north while the nurse looks to the east; a small quantity of milk is pressed out of the right breast, and before lactation the breast is washed and consecrated by the recitation of the following *mantras*, as part of the rite:

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* An English Translation of the Sushruta Samhita, Calcutta, ii (1907–16), pp. 221–232.

> "O thou beautiful damsel, may the four oceans of the earth contribute to the secretion of milk in thy breasts for the purpose of improving the bodily strength of the child. O, thou, with a beautiful face, may the child, reared on your milk, attain a long life, like the gods made immortal with drinks of ambrosia."

If a careless or inexperienced wet-nurse is employed, one who does not press out the superfluous milk before suckling, the child may be troubled with coughing, suffocation or vomiting. If there is loss or suppression of milk in the mother, from anger, grief or lack of affection for her child, her equanimity should be restored and a flow of milk brought on by a generous diet of rice, barley, wheat, wine, sesamum-paste, garlic, fish, lotus-stalk, etc. Breast-milk is tested by casting it in water. Pure and healthy milk is thin, cold, clear, the color of a conch-shell, easily miscible with water, neither floating nor sinking, and producing neither froths nor shreds. The child should not be permitted to suck from the breast of a woman who is hungry, aggrieved, tired, feverish, pregnant, who has a bad digestion, acid stomach, or is otherwise unhealthy; if medicine has to be administered to the child, it should not be suckled until the drug is assimilated.

In the diagnosis of infantile diseases, it is noted that the child constantly touches the part affected or cries at the least touch of it. If the disease is in the head, the child cannot raise it or move it about, and remains with its eyes closely shut. If the bladder is affected, there is retention of urine, thirst, pain and occasional fainting spells. If there is trouble in the colon, the affection is indicated by retention of urine, constipation, discolored complexion, vomiting, distention of the abdomen and gurgling of the intestines (colonic impaction or Hirschsprung's disease). Constant crying indicates a general infection or diathesis. Diseases of all kinds, which might affect children, are described in other parts of the Susruta, in particular "spleen belly" (enlargement and displacement of the spleen), "liver-swelling," vertigo, epilepsy, hemicrania, tetanus, malarial fever, cholera, smallpox, intestinal worms, skin and venereal affections, but as Neuburger observes, the innumerable varieties of these diseases indicate that each was "nothing but a vague symptom-complex, which, upon the slightest deviation from its supposed type, dissolved itself to reappear in a number of fresh categories."* As with the Egyptians and the Babylonians, many ailments of the eyes, teeth, ears, head, and heart were ascribed to the presence of "worms" and treated with charms. The various remedies recommended for different diseases in the Susruta are usually recommended for the same diseases in infants and children, but in doses of milder potency. In such instances, the dose is administered either through the vehicle of milk and clarified butter, or by the nurse who swallows the remedy herself, so that the child may get the effect through the breast-milk; or else plasters it as a paste over her breasts. If the child is living on solid food, the remedy is administered as a decoction. A small pinchful of medicine may be given to an infant at the end of its first month of life, if necessary. There are indications of dosage to suit the age of the child. If the child is fed on milk and rice, medicated pastes the size of plum-stones are given; if it feeds on rice or other solid foods, the dose is the size of a plum. If a nursling has fever, it should not be allowed to suck, lest thirst develop. Purgatives and emetics are forbidden, unless a disease threatens to take a fatal turn. A swollen and painful umbilicus (*tundi*) is treated by applying fomentations, medicated oils, etc. Special infantile elixirs, prepared by cooking clarified butter with decoctions of various vegetable principles are given to infants fed on liquid, semisolid or solid foods. The infant should be carefully handled, never scolded nor roused suddenly from sleep. It should be fondled and amused with toys, and never taken up or laid down suddenly. It should not be made to sit upright too early, for fear of deformation. It should not be exposed to rain, the glare of sunlight or lightning, heat, smoke or dust, nor should it be left under a tree, a vine, in low-lands, in lonely houses or caves. The child should always be kept in the inner part of the house, and to protect it from the malignant influences of evil stars and occult powers, religious rites are performed.

Such are the principles of pediatrics in the Brahminical period of Indian medicine, a clear, rational body of doctrine which is not excelled by that of any other race or nation before the Greeks or the later Europeans.

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* Neuburger: "History of Medicine," London, ii (1910), p. 56. The tendency to give to symptoms and syndromes the dignity of definite diseases or "clinical entities," standing upon their own feet, impeded the progress of medicine for a long time and is still chronic in certain quarters. The tendency is amusingly illustrated in the 228 varieties of syphilis listed by Brassavola. See C. G. Gruner, "Morborum Antiquitates," Breslau (1774), pp. 85–100.

ISRAEL

The facts and findings of Jewish medicine were never cast into the form of a definite canon, or scripture, but are scattered throughout the Old and New Testaments and the Talmud. What we know of the subject is due to the synthetic work of Thomas Bartholinus, Richard Meade, J. B. Friedreich, A. H. Israels, Julius Preuss, W. Ebstein and other scholars. The main features of Biblical medicine (Old Testament) are a clear recognition of contagion as a fact, with the institution of prophylactic measures against certain infectious diseases by the high priests (as medical police), the rigid regulation of sexual hygiene, with medico-legal *expertise* by the priests, and the institution of the Sabbath as a weekly day of rest. In Talmudic medicine, the presence of an epidemic disease in a community was actually announced by blast of trumpet. Apart from the foundation of preventive medicine, the ritual hygiene and cult-cleanliness of the Hebrews were indeed remarkable, but are attributable to the interaction of several cultures in the 8th–6th Centuries B.C., or (in a dictum of Huxley's) "only one of several sporadic indications of some powerful mental ferment over the whole of the area comprised between the Ægean and Northern Hindustan." "What are today considered fixtures of ancient Semitic cult-hygiene," says Sudhoff, "originated almost exclusively after the Exodus, therefore after the time during which the people of Israel had been exposed for decades to the influence of racially and intellectually kindred civilizations along the Euphrates and the Nile." Personal hygiene with intention, including athletics and cult-cleanliness, was largely Greek in origin. "Even ritual uncleanness of women," Sudhoff insists, "is ancient property of Greece."

In the Old Testament, diseases is attributed not to demons but to the wrath of God, who alone can confer health. In the New Testament, demons are sometimes exorcised in certain cases of "possession."

Modern civilization flows from two main streams of culture, the Hellenic and the Hebraic. Hellenism gave us science, art, and the principles of good taste; Judaism gave us religion and certain ethical principles for regulating the conduct of our lives which are the basis of all ultimate strengthening and refinement of character. That the Hebrews set great store by children is everywhere apparent. In the **Bible,** children are a blessing; childlessness is a curse.

> "The children which God hath graciously given Thy servant" (Genesis, xxxiii, 30).
>
> "Write ye this man childless, a man that shall not prosper in his days" (Jeremiah, xxii, 30).
>
> "Lo, children are an heritage of the Lord; and the fruit of the womb is his reward" (Psalms, cxxvii, 3).
>
> "Children's children are the crown of old men" (Proverbs, XVII, 6).

Tacitus (History, V, 5) ascribes the prohibition of infanticide among the Jews to their desire to increase the population.* Male children were especially valued, as future priests or soldiers, and a bright, sagacious boy was the joy of his parents:

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* Lecky, "History of European Morals," New York, ii (1869), p. 28, footnote 1.

> "A wise son maketh a glad father; but a foolish son is the heaviness of his mother" (Proverbs, X, 1).
>
> "He that begetteth a fool doeth it to his sorrow; and the father of a fool hath no joy" (Proverbs, XVII, 1).

The feeling of all ancient civilizations against female offspring is sensed in the impressive words of Jesus Sirach (XLII, 9):

> "A daughter is to her father a secret sorrow: care for her welfare robs him of his sleep; in her youth, that she may not fade; in wedlock, that she be not hated; in the time of her virginity, that she be not dishonored, nor become pregnant in her father's house; in her betrothal, that she become not frivolous; in her married life, that she be not sterile."

Under the stern moral and religious code of Israel, child-life was hedged in from the start by a veritable quickset of interdictions and inhibitions, which, as evident from the New Testament, were carried over into Christian doctrine. These teachings made for integrity and strength of character, but rendered the child's life dreary through the pragmatic character of their ethical intention. The child wishes to live uninhibited in an ideal frictionless medium, but even at the tenderest age, it has to learn that it cannot.

> "Even a child is known by his ways; whether his work be pure and whether it be right" (Proverbs, XX, 11).
>
> "Train up a child in the way he should go; and when he is old, he will not depart from it" (Proverbs, XXII, 6).
>
> "A fool despiseth his father's instruction" (Proverbs, XV, 5).
>
> "Children obey your parents" (Ephesians, VI, 1; Colossians, III, 20).
>
> "One that ruleth well his own house, having his children in subjection with all gravity" (Timothy, III, 4).
>
> "We have had fathers of our flesh which corrected us" (Hebrews, XII, 9).
>
> "Likewise, ye younger, submit yourselves unto the elder" (Hebrews, V, 5).
>
> "Now I say that the heir, as long as he is a child, differeth nothing from a servant, though he be lord of all. But is under tutors and governors until the time appointed of his father" (Galatians, IV, 1–2).

In the older texts, rebellious or refractory children are viewed with the severity of the Code Hammurabi.

> "And he that smiteth his father or his mother, shall be surely put to death" (Exodus, XXI, 15).
>
> "Cursed be he that setteth light by his father or his mother" (Deuteronomy, XXVII, 16).
>
> "The eye that mocketh at his father, and despiseth to obey his mother, the ravens of the valley shall pick out, and the young eagles shall eat it" (Proverbs, XXX, 17).
>
> "Whoso curseth father and mother, let him die the death" (Mark, VII, 10).

In Deuteronomy (XXI, 18–21), a stubborn and rebellious son shall be stoned to death by the elders of the city. The little children who mocked the baldness of Elisha were cursed by the prophet, and forty-two of them were torn by two she-bears that came out of the wood (II Kings, II, 23–24).

Instances of sacrifice of the first-born, as in the case of Abraham and Isaac (Genesis, XXII), or of Mesha, king of Moab, who sacrificed the eldest son of the king of Edom (II Kings, III, 27), evidently go back to remote antiquity; for, as with the Greeks and Romans, this rite was, in time, modified by the substitution of some animal as a scapegoat. The hideous rite of passing children through the fire to Moloch was of Phœnician origin, and practiced by the Carthaginians. It fell upon Israel through the insidious effect of contact with the idolatrous ritual of barbaric peoples. Thus, Ahaz, king of Jerusalem, "burnt his children in the fire, after the abominations of the heathen whom the Lord had cast out before the children of Israel" (II Kings, XVI, 3; II Chronicles, XXVII, 3). Manasseh, who ruled fifty-five years in Jerusalem, "made his son pass through the fire." The practice was severely denounced in the fulminations of the Hebrew prophets:

> "For when ye offer your gifts, when ye make your sons to pass through the fire, ye pollute yourselves with all your idols, even unto this day" (Ezekiel, XX, 31).
>
> "Against whom do ye sport yourselves? Against whom do ye make a wide mouth, and draw out the tongue? Are ye not the children of transgression, a seed of falsehood,
>
> Inflaming yourselves with idols under every green tree, slaying the children in the valleys under the clefts of the rocks?" (Isaiah, LVII, 4–5).
>
> "Yea, they sacrificed their sons and their daughters unto devils, and shed innocent blood, even the blood of their sons and daughters, whom they sacrificed into the idols of Canaan: and the land was polluted with blood" (Psalms, CVI, 37–38).

Our knowledge of ancient Jewish pediatrics is mainly drawn from that great body of scholastic and mystic commentation on the five books of the Mosaic law (Torah or Pentateuch) which began to accumulate after the Babylonian captivity (536 B.C.) and which makes up the **Talmud.** In contradistinction to the written law of the Torah, the Talmud consists of the law transmitted by verbal tradition (Mishna) with its many interpretations and commentaries (Gemara). There are two Talmuds: The Palestinian, completed 370–390 A.D., and the Babylonian, completed 352–427 A.D. The Babylonian Talmud is the Talmud of ordinary reference.

In the Talmudic ritual which attended the ushering of the new-born child into the world, there is evidence of ancient practice, and also of superstition. If the child was born with a caul, it was a sign of good luck. If it was a boy, he was greeted with the phrase: "A blessing has come into the world;" if it was a girl, "the walls wept." A cedar tree was planted at the birth of a boy; a pine tree for a girl. The Shema or Psalm XC was read in the presence of the children of the community for the protection of the new-born. There were visitations to the infant boy on the first Sabbath of his life. In Talmudic times, the infant was weighed and its body-weight in coins was given to the poor. Amulets and charms, such as the suspension of Torah scrolls or verses of the Psalms over the bed, or the chalking of circles on the wall or the floor of the lying-in room, were in evidence. The cradle was sometimes hung with bells to ward off evil, a feature of the amulets of modern Spain. The ceremonial of "redemption of the first-born" came on the thirty-third day after the birth of a male, and the sixtieth day after the birth of a female. The child's hair was not cut until its fourth birthday, lest it acquire an elf-lock. Its religious instruction began in the fourth year. It had to learn the Torah at five, the Mishnah at ten, and "fulfilled the whole Law" at thirteen. Girls as well as boys were sent to the synagogue, where both were kept apart, as showing scant reverence through their playful impulses. Swimming and handicraft were taught, but the Jewish children acquired their games from the people among whom they were living.* The cradle-songs usually enjoin upon the infant that it study the Torah. The following little *berceuse*, translated from the Yiddish in the Jewish Encyclopedia,† has the spirit of "A Child's Garden of Verses," and suggests that bears were fearsome objects to Eastern European children:

> "Beggars and bears are all around;
> They even walk around outside,
> And if they find pretty girls are crying
> They seize them and throw them into the well."

On the day after birth, circumcision was performed upon male children of freemen and slaves, in token of the covenant between God and Abraham. In Biblical times, the operation was performed by the mother, usually with a primitive chipped flint (Exodus, IV, 25). The rite was not in the nature of a sacrament, but was regarded as indispensable to consecration and purification. To be uncircumcised (*arel*) was a reproach, but an uncircumcised Jew still remained a Jew. Aliens had to be circumcised before they could partake of the Passover (Exodus, XII, 48) or marry a Jewish woman (Genesis, XXXIV, 14–16). The rite can be performed by a physician as well as a priest. In the time of Josephus, it was in the hands of a surgeon (*mohel*). The rite of circumcision originated in Egypt. All that came out of Egypt were circumcised (Exodus, IV, 24–26), but those who came out of the Wilderness were not (Joshua, V, 2–9). Circumcision is a widespread custom throughout the Mohammedan world, was probably acquired by the Aztecs by the convection of Egyptian culture (Elliot Smith),‡ is common in Australia, Northern and Central Africa, among the Amazon tribes of South America and the Polynesians of the South Seas. Aboriginally, it is a rite of initiation or consecration of the generative powers at puberty. In the Jewish ritual, it has three stages: the excision of the foreskin (*milah*); the rolling back of the prepuce (*periah*), and the sucking of the wound (*mezizah*), which has sometimes exposed the infant to inoculation with syphilis. The necessity of circumcision in proselytes was abolished in 1892.§

At birth, the Jewish child was washed in water, rubbed with salt, given the breast even before cutting the umbilical cord, and wrapped in swaddling clothes. This procedure, essential in the Talmud, is preserved even in the imprecations of Ezekiel against Jerusalem:

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* Jewish Encyclopedia, New York, iv (1903), pp. 27–31.
† *Ibid.*, p. 332.
‡ G. Elliot Smith, "The Migrations of Early Culture," Manchester (1915).
§ Jewish Encyclopedia, New York, iv (1903), pp. 92–102.

> "And as for thy nativity, in the day thou wast born, they navel was not cut, neither wast thou washed in water to supple thee; thou wast not salted at all, nor swaddled at all" (Ezekiel, XVl, 4).

The salting of the child, which was also a custom of the Greeks, was thought to give it a thicker, tighter skin (Galen), with immunity from eruptions. Osiander thought the "salt" was bicarbonate of soda, which forms a soap with the vernix caseosa. In Talmudic times, the new-born infant was also bathed in wine. If it made no sound, it was rubbed with the afterbirth. If the child did not breathe, it was, according to the Babylonian Talmud, swung in a swing, probably the method for relieving asphyxia neonatorum introduced by C. B. Schultze (1871). If it refused the breast, a beaker with hot coals was held near its mouth to stimulate the facial muscles. The swaddling of the child, known as *laphaph* in the Talmud, consisted in compressing its body into a rigid mummy-like mold by a system of tight bandages. The intention was perhaps orthopedic, as the head was also compressed to make it long or round. The mouth was washed to incite vomiting of mucus. In the daytime, the child was rocked in its cradle; at night, it slept with its mother, whence there was danger of suffocation by overlying.

In the third month of pregnancy, it was supposed by the Greeks, the Hebrews and the Arabs that suppression of the menses acquired an economic function; the menstrual blood clouded to become milk. According to Jewish custom, the child was given the maternal breast immediately or within 24 hours after birth, even if the cord had not been cut, which is different from ancient Greek and Indian practice.

The ancient belief that honey purges the new-born of meconium is preserved in Isaiah (VII, 14, 15):

> "Behold a virgin shall conceive, and bear a son, and shall call his name Immanuel. Butter and honey shall he eat, that he may know to refuse the evil, and choose the good."

Talmudic theory maintains that the child can suck all day without harm. The night was divided into three watches, and in the third watch, before dawn, the infant was given the breast. The child was suckled for a period of 18 months or two years. In the second book of Macabees (VIII, 27), a mother tells her son that she suckled him for three years. Rabbi Joshua held that breast-nourishment may continue for an unlimited period, even five years, if necessary. Sarah suckled her son Isaac at the age of ninety (Genesis, XXI, 7–8). Breast-nursing was regarded as a primal duty of the mother by the Hebrew prophets:

> "Can a woman forget her sucking child, that she should not have compassion on the son of her womb*" (Isaiah, XLIX, 15).
>
> "Even the sea monsters draw out the breast, they give suck to their young ones; the daughter of thy people is become cruel, like the ostriches in the wilderness. The tongue of the sucking child cleaveth to the roof of his mouth for thirst;

the young children ask bread and no man breaketh it unto them" (Lamentations, IV, 3–4).

If the husband of a nursing mother died, she was not allowed to marry again within 18–24 months, lest a new pregnancy interfere with the nourishment of the first child. The time limit for lactation also determined the minimum period within which a widow could marry. If the mother died, the father could provide artificial nourishment for his infant, but these things could not be entrusted to a step-father. The ancients did not credit the theory that lactation hinders conception. The ethical ideal was that specified in Hosea (I, 8):

> "Now when she had weaned Loruhamah, she conceived and bare a son."

A rabbi would not allow a widow whose infant had died to marry until 24 months after its birth, because a certain widow had once made away with her child in order to marry earlier. No wife was required to suckle her neighbor's child. If there were twins, one was suckled by a wet-nurse. It was adjudged shameless to suckle infants in public. If a husband forbade his wife to suckle her child, her will and pleasure obtained in the matter, since the labor and trouble were all her own. If she declined to suckle her infant on her own account, the case was decided by the custom obtaining in her family. If the mother was not capable of suckling, on account of sickness or otherwise, a wet-nurse was engaged, usually a slave or hired woman. As in the Alexandrian slave contracts, she was engaged for 2–3 years, undertook no other occupation, and suckled no other child, not even her own. Whether a nurse alien to the Jewish faith could be employed was disputed by the rabbis. She might kill the child by rubbing poison on her breasts. The Jewish women seldom employed alien nurses as their breasts were well developed. When Moses was found by Pharaoh's daughter in the ark of bullrushes, his mother was secured as his wet-nurse by the stratagem of his father's sister (Exodus, II, 7–9). A wet-nurse was held responsible for the fate of the nursling. Like Deborah, the nurse of Rebekah, she was regarded as a member of the family and held in esteem, if competent. During lactation, a nursing woman worked little and fed well. She might take wine, but no articles which might spoil the milk or lessen the supply of it. Hops, green corn, figs, small fish, etc., were interdicted. A supply of "pure unadulterated milk" was specified in the Alexandrian wet-nursing contracts. Both wet-nurses and nursing mothers had to observe the fast-days. There is no mention of artificial feeding in the Talmud. The child must have milk or die. The mother's milk was sometimes milked from the breasts and given in a glass or the horn of an animal, in the case of a new pregnancy. Sucking immediately from the udders of a cow or goat was customary in antiquity, as in the mythological instances of the Egyptian cow-goddess Hathor, or of Zeus and Amalthea, or Romulus and Remus. Suckling from the male breast is recorded in one case in the Talmud. There is no evidence of the existence of nursing bottles, although they were employed in Rome and Alexandria. At the weaning of the child, the Hebrews in the desert held a feast (Genesis, XXI, 8; I Samuel, I ,24–25). This practice, however, disappeared in Talmudic times.*

Beyond the case of the raising of the widow's son by Elijah (I Kings, XVII, 17–23), the resuscitation of the son of the Shunammite woman by Elisha (II Kings, IV, 18–35), which Preuss surmises to have been a case of sunstroke, and the raising of the daughter of Jairus by Jesus (Matthew, IX, 18, 23–25), there is little mention of children's diseases in the Old or the New Testament. Of the many diseases mentioned in the Talmud, the most dangerous to children was the *askara* (ἐσκάρα) or *serunke* (συνάγχη), that is, *cynanche, squinantia* (quinsy) or diphtheria, identical with the "Egyptian or Syrian ulcer" of Aretaeus. So much was this disease feared by the Hebrews that the first case located in a community was immediately heralded by a warning blast of the trumpet, although the *shofar* was usually sounded, under ordinary circumstances, only after the third case of an epidemic disease. The painful struggling of the suffocating patient was regarded as the most terrible of the 903 known varieties of death. Rabbi Josef said that whoever was guilty of strangling a person to death would either be drowned, strangled by the heathen, or die of *serunke*. Rabbi Ismael ben R. Jose describes the disease as follows:

> "*Askara* is a much-dreaded epidemic disease which usually attacks children, is located in the throat, and kills the patient by a painful death from suffocation."

To avert it, there was an apotropaic diet: lentils were eaten daily, all food was salted and water mixed with every drink. Lentils or juice of lentils were recommended as a remedy by Rabbi Jochanan. During the Temple period, the priest on guard fasted every Wednesday to prevent children from catching the disease. In the Karaitic prayer-book, there is the following verse for Wednesday:

> "And *askara*, which Thou hast joined to this day: protect the children of Thy people from it, that it may not come into their mouths."

Dysentery (*chôlî mê 'ajîm*) was also much feared, and was doubtless of the tropical variety. Another disease affecting childhood and youth was the *jêrâquôn* (pallid anemia). Heat-stroke in a three-year old boy at harvest time, with cerebral symptoms, has already been noted (II Kings, IV, 18). Biliary disorders (*choli*), jaundice in particular, were common complaints throughout the Jewish and Mohammedan world. They were treated by a mixture of barley, *Carthamus tinctorius*, and salt (Rabbi Josef). This draught, which the Gemara declared to be identical with the Egyptian *zythos*, was called "spear-water" (*mé dequarin*), because it penetrated the bile. Dropsy (*hadrôquan*), intestinal worms (*kinnim*), phthiriasis (*rimmâ*), scorbutic stomatitis (*caphdînâ*) are features of Talmudic medicine. Beautiful teeth and an odorless breath were a personal ambition. *Fœtor ex ore* annulled marriage in a woman, and annuls even a betrothal in Prussian law. The foul breath of the adulteress was an observation of the Talmud (Numeri, r. IX, 21). To keep the breath odorless, *mastix* was chewed, pepper, cinnamon or ginger were held in the mouth, and the teeth were rubbed with a dry powder. Toothache and dental caries were treated by boring, scraping away tartar and implantation of artificial teeth. Gargles were given for tonsillitis and laryngitis (*gârôn*). Milk was drunk frankly from the udders of the goat for lung affections, but there are no words for "cough" or "phthisis" in Hebrew. The arid plains of Palestine were, from of old, inimical to pulmonary disease (Liebermeister).*

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* These details are derived from J. Preuss: "Biblisch-Talmudische Medizin," Berlin (1911), pp. 466–477; W. Ebstein: "Die Medizin im alten Testament," Stuttgart (1901), pp. 64–67; and Ebstein: "Die Medizin im neuen Testament und im Talmud," Stuttgart (1903), pp. 216–219.

HELLAS

In the **Homeric Period** (950 B.C.), infants, when not exposed, were usually nursed by their own mothers. Thus Hecuba reminds Hector how she once gave him "the grief-lulling breast" (*Iliad*, XXII, 82–83); Achilles is described as one "whose mother nurtured him in wrath" (XVI, 203) and there is reference to Penelope as a young bride with "an infant boy at her breast" (*Odyssey*, XI, 448). Among the upper classes, slave-nurses, sometimes captive women, were also employed. Odysseus says to his aged nurse Eurycleia: "Why dost thou wish to destroy me? Thou thyself didst nourish me at thy breast" (XIX, 482), and we learn that Eurycleia had been purchased by Laertes in her youth for a hundred beeves (I, 9), and that she rose to high rank in the household, supervising the fifty female slaves (XXII, 421). The nurse in Homeric life was, like the nurse in "Romeo and Juliet," a member of the family, indeed the general housekeeper. Thus Demeter, in the Homeric hymn (141–144):

> "And truly I could fitly nurse a young infant, having him in my arms, and could take care of the house and could spread my master's bed in the recess of the well-built chambers, and could manage the works of woman."

For such service, as we learn from the same hymn to Demeter (166), even a slave-nurse was richly rewarded. The nurse's duties to the infant were to bathe it in water immediately after birth, to wrap it in swaddling clothes, usually of white, purple or saffron color, with gold bands (Hymn to Apollo, 121), to fondle it and carry it about, and to suckle it until it could be fed on honey or the juice of figs. Care was taken to carry the child until it could stand and walk without distorting its limbs. It was carefully washed and dressed, and cradled in a shield, a shoe-shaped two-handled basket, or in a basket woven of twigs for winnowing corn (λικνόν), which, as being sacred to the gods, was regarded as a symbol of future wealth and prosperity. Dolls, rattles, balls, animals made of clay, and other toys were provided, and stories, designed to form the child's mind, were told, even down to the time of

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* J. Preuss: "Biblisch-talmudische Medizin," Berlin (1911), pp. 172–433, *passim.*

Galen (*De temperamentis*, II, 578). As a rule, the nurse remained the devoted attendant of the grown-up son or daughter in after-life.*

As set forth in the laws of Lycurgus (880 B.C.), which are said to have been based upon his observations in Crete, Ionia, and Egypt, the children of **Sparta** were reared in a different manner from that obtaining in the aristocratic milieu of the Iliad and the Odyssey. In Plutarch's life of Lycurgus, we read that eugenics, or the securing of a vigorous parentage to offspring, was practised without any regard for conventional morality; that "children were not so much the property of their parents but of the whole commonwealth"; and that puny, ill-formed children were exposed in a chasm under Mount Taygetus, since it was "neither for the good of the child itself, nor for the public interest that it should be brought up, if it did not, from the very outset, appear made to be healthy and vigorous."

> "Upon the same account, the women did not bathe the newborn children with water, as is the custom in all other countries, but with wine, to prove the temper and complexion of their bodies; from a notion they had that epileptic and weakly children waste away upon their being thus bathed, while on the contrary, those of a strong and vigorous habit acquire firmness and get a temper by it, like steel. There was much care and art, too, used by the nurses: They had no swaddling bands; the children grew up free and unconstrained in limb and form, and not dainty and fanciful about their food; not afraid in the dark, or of being left alone; without any peevishness or ill humor or crying. Upon this account, Spartan nurses were often brought up or hired by people of other countries; and it is recorded that she who suckled Alcibiades was a Spartan."†

Up to the age of seven, male children were kept in the gynaeceum under the care of women; from 7 to 18 they were called "boys" (*πρωτείρες* from 18 to 30 "youths" (*ἐφῆβοι*), at 30, they attained to manhood. Education of boys was mainly physical—running, leaping, wrestling, boxing, etc., and was conducted in a gymnasium. Dancing, military exercises and the chase made up the rest. At the festival of Diana Orthia, the flogging of certain boys (*διαμαστίγωσις*) was practised to teach endurance to pain. Girls also wrestled, ran races, threw quoits, cast spears and danced in public in a state of nudity; and, as Sudhoff says, "the regulation of sexual life in the gymnastic exercises of girls was divorced from prudery and had a definite eugenic aim: vigorous offspring."‡ Out of this stock came alike the heroes who fought at Thermopylæ, and "Heaven-born Helen, Sparta's queen," whose fatal gift of beauty caused the Trojan war.

In **Hellenistic Athens,** infants were wet-nursed not only by slaves and captives, but also by free women, usually through poverty and the necessity of supporting dependents in this manner. But even when slave-nurses were set free, they still remained in the service of their masters, and like the free-born woman of the metic class, received a living wage. Foreign nurses were sometimes employed by the Athenians. The Spartan women were usually preferred, on account of their robust physique and their sturdy, wholesome natures. Aristotle attributed infantile diseases to faulty diathesis in the nurse (*Historia animalium*, VII, 10). Corinthian and Phrygian women were also favored, and, like all metics, received compensation.* The practice of swaddling the infant continued down to the late Roman period, was described in detail by Soranus, and was carried over into medieval custom. It was derided by Plato, who proposes that nurses should be compelled

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* These details have been brought together in the graduating dissertation of Sister Mary Rosaria on "The Nurse in Greek Life "(Boston, 1917), an admirable summary.

† Plutarch's Lives (A. H. Clough), *sub voce* "Lycurgus."

‡ Sudhoff: Ann. Med. History, N. Y., i (1917) p. 112; translation of Dr. Frank J. Stockman.

> "under penalty of a legal fine to be always carrying the children somewhere or other, either in the country, or to the temples, or to their relations' houses, until they are well able to stand and even then they should be careful that their limbs are not distorted by leaning on them when they are too young. They should continue to carry them until the infant has completed its third year" (Laws, IV, 789).

In the same passage he likens the effects of dandling and rocking of infants to the soothing, restful movements of a swing, horseback riding or the sea. Further, he says that nurses judged of the mood of a child by the effect of something offered it: when it is silent, it is pleased; when it weeps and cries out, it is angry (792). The use of wine, by nurse as well as child, was condemned by Aristotle (Politics, VII, 7), and Hippocrates says (*De aere, aquis et locis*, I, 9)† that to avoid the formation of calculus by unwholesome milk, it is better to give children wine copiously diluted with water, as this beverage tends less to burn and dry up the veins. Amulets and charms against witchcraft were still used, and the nurse commonly spat toward an approaching stranger to ward off the evil eye or other malevolent influence (μίασμα) which might emanate from his person. The nurse taught the child to distinguish objects by their names, spanked it with the sandal on occasion (Lucian), and told it the usual nursery tales. To frighten into good behavior, gruesome stories were told about Lamia, the vampire, who devoured children alive, the Gorgon, the minions of Hecate, the Cyclops and other terrifying figures. To amuse children or put them to sleep, mythological stories were told, such as the infancy of Hermes, the adventures of Odysseus or the labors of Hercules. Plato, in the Republic (II, 377–383), Aristotle and Plutarch discourse at great length upon the importance of censoring the episodes in Greek mythology as tales for the young, so that what was immoral and pernicious might be avoided. The Greek lullabies for infants were probably rhythmic songs without words (Aristotle) or with word improvised by the nurse. Beautiful examples are found in the poets, such as the lullaby of Alcmena in Theocritus (XXIV, 6–8), the Lament of Danae in Simonides (Fr. 37), or the nurse's song in the Orestes of Euripides (174–182).‡

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* Sister Mary Rosaria, *op. cit.*, pp. 12–15.

† Littré's Hippocrates, ii, p. 41.

‡ Sister Mary Rosaria, *op. cit.*, pp. 34–44.

Over all child-life in Greece, Homeric, Spartan, or Athenian, was the glorious *plein air* of Hellenic culture. Innumerable terra cotta figurines and reliefs exist, representing the suckling, dandling, bathing and fondling of infants, the games of children, and the amulets employed to protect them (Dresden Catalogue, items 4051–4212). Sudhoff summarizes as follows:

> "Even though the exposure of weakly or unwelcome children, in Greece (Sparta) and Italy, as well as in the Orient, left an ineradicable stain, yet the Greek upbringing of children, in its harmonious development of body and spirit, is a wonderful phase of hygiene. The love which invested the earliest period of child-life is apparent in the profusion of imagery which tells of the first bath of the new born, its swathing and cradling, the suckling of the infant at the breast of mother or wet-nurse. In the later period of Hellenistic Egypt, infants were in care of wet-nurses, who gave them six months breast-nourishment and eighteen months of artificial milk-diet, as attested by the many nursing bottles which continue to be found in children's graves. The same principles applied to infant nutrition in Confederated Hellas, but the children remained at home in charge of mother or wet-nurses, among whom the Spartan women were particularly prized, although the Spartan habit of rearing without swaddling clothes does not appear to have taken hold elsewhere. In children's games of all kinds, the Greek spirit was everywhere inventive. The plaything was often designed for games of running and jumping; with older children the ball, the hoop, the peg-top were as popular as with adults of both sexes; as also the swing, the see-saw, the kite, the hobby-horse, the go-cart, pitch and toss, etc., which were carried over directly into the gymnastic exercises of later years."*

In Greek medicine before the time of Soranus of Ephesus, the pediatric element is scattered at random through the literature, as with the pediatrics of the Talmud. Greek medicine, as a contribution to science, begins with **Hippocrates** (460–370 B.C.).

A strange superstition of antiquity was to the effect that a seven-months child is sometimes viable, but an eight-months child undergoes certain pathological changes in the uterus, due to sinking and altered relation of the fetus in utero, which renders it unfit for birth and extra-uterine life. A ten-months child was regarded as more vigorous and fit for life than even a nine-months child. Discussion of this matter forms the theme of the Hippocratic treatises on the seven- and eight-months child.

In the Hippocratic canon, there are innumerable references to the hygiene and diseases of infancy and childhood.

Thus in the apocryphal books on Epidemic Diseases (IV–VII) we find cases diagnosed by Littré as opening the chest by cauterization for empyema, in a child of Philis (IV, 4); head injury in a son of Metrophantus, with fever, trephining and death on the 24th day (IV, 11); gangrene of the mouth in two children (IV, 19); disease of the bladder in a son of Theophorbus of Larissa (V, 17); fatal impalement of a child by a boar's tusk (V, 39); phagedenic ulcer of the mouth in a son of Athenades (V, 44); fatal tetanus from a sprain in Telephanes, son of Harpalus (V, 75); and from irritation of a wound by a drug in Thrino, son of Damon (V, 76); gangrene of the jaw from toothache, in a child of Metrodorus of Cardia (VI, 100); meningitis from caries of the petrous portion of the mastoid (VII, 5); an epileptic fit in a son of Anechetus (VII, 46); and an umbilical fistula with procidence of the intestine in a child of Dinias of Abdera (VII, 117).

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* Sudhoff: Dresden Catalogue (1911), p. 138.

In the genuine books on Epidemic Diseases (I–III), there are authentic and valuable descriptions of the semeiology of phthisis, dysentery and diarrheal diseases, malarial and hæmoglobinuric fevers, gangrenous erysipelas and ergotism, epidemic parotitis and anthrax. In the account of epidemic parotitis in the island of Thrasos, the simultaneous painful swellings in the salivary glands and testicles were already noted, although the orchitis was first featured as such by Hamilton in 1761. The Hippocratic treatise on the joints (*περὶ ἀρθρων*) is a scientific account, almost modern, of the different congenital deformities of the foot and spine and the various dislocations and their treatment. In this treatise (§41), and in the Aphorisms (VI, 46), it is noted that a gibbous spine (Pott's disease) often coexists with tuberculosis of the lungs; and the Calot treatment of spinal deformity by forcible reduction (*redressement forcé*) is applied for the first time (§47). In the treatise on Wounds of the Head (XXIX) Hippocrates says that children die more quickly of wounds than adults.

In the treatise on Prorrhetics (Littré, IX, 52), it is recognized that prolapse of the rectum may accompany obstinate diarrhea or calculus in children. For treatment, it is recommended that the rectum be replaced with soft sponges, the child being suspended with hands tied; or in obstinate cases, moisten the rectum with a sponge sopped in a decoction of lotus (*Celtis australis*, Littré), compressing the rectum by means of a bandage passing around the abdomen and between the legs. At stool, the child sits with its back against its mother's knees, its feet upon her feet.*

In his commentary on the treatise *De morbis* (*περὶ νοῦσων*), Littré (VII, 25–161, *passim*) diagnoses:

> Cases of otitis media, otitic abscess of the brain, tonsillitis, inflammation of the tongue, uvula, epiglottis and palate, removal of nasal polypi with a string snare or by cauterization, jaundice, bilious, tertian and quartan fevers, pleurisy, bronchitis, abscess of lung with paracentesis, phthisis and laryngeal phthisis, spermatorrhea (*phthisis dorsalis*), hydrothorax with paracentesis, chronic pneumonia, pulmonary hemorrhage, melena (black vomit), tetanus, ileus, ischias (coxalgia), dropsy, hydatids, hepatitis, splenic disease, renal tuberculosis, rheumatic disorders and scurvy. Any of these may have affected childhood.

"Infantile convulsions supervene," says Hippocrates, "when there is acute fever or constipation, insomnia or sudden fears, or when the child groans, changes color, and the face becomes yellow, livid, or red. These accidents easily affect infants up to the age of seven. Older children and adults are less exposed to convulsions in fever, unless there are such violent and fatal complications as take place in frenzy" (Prognostics §24, Littré, II, 187). In the discourse on the Sacred Disease, epilepsy, which the ancients regarded as due to divine possession, is treated as a cerebral affection due to congestion of cold mucus in the warm blood, unless it is evacuated by ulcers or other channels. Epilepsy, then, attacks such children as have been spared the affections which would relieve them of the slimy material commonly voided in uterine life (Littré, XI, 367).

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* T. Kroner: Jahrb. f. Kinderheilk., Leipzig, xi (1877), p. 256.

If it is fear of the divinity that leads adults to seek seclusion in an epileptic fit, children are apparently not so superstitious. They fall where they stand, or if they can perceive the aura from the experience of several attacks, they run in terror to their mothers or to some one they know (*Ibid.*, 383). The presence or possibility of epilepsy in children is known by "sudden distortion of the eyes, by tumors on the neck, or when a grave accident has been sustained or the voice is shrill, or there is chronic cough, or lateral distortion, or varix of internal veins or prolapsed omentum, or an enlarged testicle or a helpless, shrivelled arm, or paralysis of the lower limbs, or if a more mature child feels bodily pain from urethral discomfort. Most people who have care of such children will admit epilepsy; others deny it through ignorance."

Ascarides and tenia are considered in the treatise *De morbis* (IV, 54).

Flat and round worms are held to be engendered in the fœtus. Round worms reproduce themselves; flat worms do not. Hippocrates notes the great increase in size of the tænia—"as long as the intestine itself," in which case parts of it may be voided in the stools or even in walking. If the child is purged without a vermifuge, this will bring away only parts of the worm. The worm is regarded as sometimes impinging against the liver, causing dribbling of saliva, aphonia, jerking sensations in the abdomen and pain.

Cystitis is treated in the Prognostics (19).

Febrile affections of the bladder may cause death, if they persist; there is constipation, or the voiding of hard dejecta on purgation, and purulent urine. If the fever continues, death will supervene in the early stages of the disease, especially in children from 7 to 15 years of age. In the treatise *De morbis* (IV, 55), there is a long discourse on calculus in children, to which Hippocrates devoted particular attention. His views were merely repeated by the later authorities and the Middle Ages added little to the subject (Kroner). In Hippocrates' view, lithiasis in children was due to impure milk. The greater frequency of calculus in boys is noted (Kroner says that 40 per cent. of all cases occur in children under ten, usually boys). Girls are less affected because "they drink more water than boys and the female urethra is shorter and wider." The observation that calculus in boys may be due to mother's milk suggests the exudative diathesis. The formation of sediment from impure urine in the bladder is likened to the settling of sediment in turbid, impure water; the sediment is held to come from a mixture of mucus in the milk with the urine. The five signs of calculus are pain in urination; the emission of urine drop by drop; bloody urine, if the bladder is ulcerated by the stone; inflammation of the bladder with reflex pain at the prepuce; sometimes emission of sand with the urine. In urinary calculus, male infants will handle and rub the genitals; girls do not. For calculus in girls, Hippocrates prescribes a drachm of the leaf of Ethiopian root (*Salvia æthiops*, Littré) in old urine for 10 days, the same in water for 20 days thereafter, and warm baths twice daily.

The treatise on Airs, Waters and Places contains a number of valuable pediatric observations.

In places which are warm, moist and swampy in summer and cold in winter, children will suffer from respiratory disorders, convulsions and a tendency to epilepsy. In places with changeable weather and cold winds, nurslings will get little mother's milk on account of the hardness of the water. Hydrocele is frequent in cold, windy places and disappears in children as they grow. Marshy, stagnant, evil-smelling waters in lakes and ponds produce large, hard (malarial) spleens, stiff, emaciated bellies, with emaciation of the face, shoulders and clavicular region; also fatal dropsies, diarrheas, and prolonged quartan fevers; in winter, there are dropsical, wasted children, with liability to hernia. Pregnancy in warm, changeable winters or in springtime with cold, northerly winds may lead to abortion or to weak, sickly children. The late advent of puberty in cold climates is noted, also the tendency of Asiatics to deform the infantile cranium by bandages and machines.

A few of the *Aphorisms* bearing on pediatrics may be cited.

"Elderly people bear fasting well; infants poorly, especially those of lively disposition" (I, 13). Galen rightly interprets "fasting" here as "spare diet":

"The growing organism has the most innate (animal) heat and therefore requires more nourishment (I, 14).

"Liquid diet is proper in all febrile diseases, particularly in children (I, 16).

"Treat epilepsy in the young by change of air, environment and mode of life (II, 45).

"Children born in a mild, calm, rainy winter or a cold spring are apt to be puny and unhealthy (III, 12).

"Children are most comfortable and healthy in spring and early summer (III, 18).

"The diseases of new-born infants are aphthæ, vomiting, insomnia, night fears, inflammation of the umbilicus, and discharges from the ears (III, 24).

"At teething, there are pruritus of the gums, convulsions and diarrhea, especially when cutting the canine teeth, and in fat, constipated infants (III, 25).

"A little later. there are tonsillar affections, crick in the neck, asthma, calculus, round worms, warts, scrofula, tumors about the ears and elsewhere (III, 26).

"At the approach of puberty, epistaxis and chronic fevers supervene (III, 27).

"Infantile diseases which do not pass away at puberty become chronic (III, 27).

"Difficult deglutition and suffocation in fever, without swelling of the neck, is a fatal symptom (IV, 34–35).

"Frights or convulsions after sleep are bad symptoms; stoppage of respiration in fevers indicates convulsions (IV, 67–68).

"Epilepsy before puberty may change for the better; after 25 it is usually fatal (V, 7).

"Rolling of the eyes in sleep is bad, unless connected with loose bowels (VI, 52).

"Acid eructations in diarrhea are of good omen (VI, 1).

"Those who acquire humped backs from asthma or cough before puberty will die" (VI, 46).

With Hippocrates, Greek pediatrics, in the proper sense of the term, culminates and ends.* After the destruction of Corinth (146 B.C.) Greek medicine was transplanted to Rome, and its greatest representatives in Rome came, not from Athens, Corinth or Thebes, but from the peninsula of Asia Minor.

ROME

From Rome came the first laws for the protection of children, but there was to be a long struggle with infanticide, the systematic destruction of female infants and the inhumanities of the *patria potestas*. "The Roman policy," says Lecky, "was always to encourage, while the Greek policy was always to restrain population, and infanticide never appears to have been common in Rome till the corrupt and sensual days of the Empire."† According to legendary tradition, Romulus, the founder of Rome, who had been an exposed infant himself, decreed that all male infants who were not monsters or otherwise malformed were to be reared, as also the first born of all female infants. The object of this ruling was to breed a warlike race, with a superabundance of males as soldiers. Even the Roman census of population was centered on estimating the fighting strength of the nation. To Numa Pompilius (715–673 B.C.) is ascribed the law cited in Justinian as *lex regia de mortuo inferendo*, which decreed that a woman who had died in pregnancy should not be buried until the child had been excised from her body, lest the hope of the living perish in the grave. From the "sombre Puritanical Sabine" came another feature of early Roman law which was to react against youthful freedom with frightful force, namely that part of the *Jus Quiritium* which made chattels of wives and children, so that a father could sell, mutilate or even kill his own offspring at will (*patria potestas*). Numa Pompilius, with the idea of encouraging marriage in young people, amended this hard rule to the extent that a father lost the power to sell his son when the latter obtained consent to marry. Under the Roman Republic (509 B.C.) the *patria potestas* continued in full force. In the Laws of the Twelve Tables it is stated that a son went free after being sold three times by his father. The exposure of infants is a common dramatic motive in the comedies of Plautus and Terence.

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* For a study of the pediatrics of Hippocrates as compared with the views of modern writers, see J. W. Troitzky: "Hippocrates als Kinderarzt," Arch. f. Kinderheilk., Stuttgart, xxix (1900), pp. 223–247.

† Lecky: "History of European Morals," New York, ii (1869), pp. 28–29.

In the best days of the Roman Republic, private life, particularly married life, was sacred, and there was even a tax on bachelors. In the last days of the Republic, depravity was rampant everywhere, celibacy, divorce and abortion were frequent and unwelcome children were thrown into the Tiber. To encourage marriage and increase the population Augustus Cæsar proposed the *lex Julia* (adopted 4 A.D.) and the *lex Papia*, which put a check upon the abuses of the *patria potestas*.* Celibates were not permitted to inherit, and a childless husband could inherit only one half of property or of moneys willed to him. In candidacy for office, preference was given to the father of the largest family; fathers of three or more children were relieved from taxes, and the senior of the two consuls was held to be he who had the greater number of children. Anyone who reared an orphan was rewarded. Through these laws, children acquired a new importance by conferring rights and privileges upon the father, and the people, as inheritors of the childless acquired, in the phrase of Tacitus, the fictitious title of "universal parent." Yet the great historian says that, "to enforce this regulation, informers were encouraged. The genius of these men knew no bounds: they harassed the city of Rome and stretched their harpy-hands all over Italy. Wherever they found a citizen, they found a man to be plundered." This attempt at regulating the population by paternal government could not thrive. Celibacy continued popular, and, in spite of subsequent relief from espionage, these laws were abolished by Caracalla and Constantine. Gibbon begins his "Decline and Fall" with a memorable eulogy of the reigns of Nerva, Trajan, Hadrian and the two Antonines as the happiest and most prosperous period in all Roman history. Payne calls these rulers the "emperors of the children." In the reign of Nerva, there was an attempt to diminish the **exposure and drowning of infants** by founding colonies for poor families and assisting indigent parents (97 A.D.). This philanthropy was furthered by Trajan, and in 100 A.D., some 5,000 children were cared for by the State. A Roman coin represents Nerva dispensing charity to children with the inscription "Tutela Italia." The younger Pliny settled 500,000 sesterces on the city of Como for the maintenance of children of good families, and a tablet of the Ligurian town of Velia shows that the interest on land mortgages went to the support of poor children (Payne). Hadrian (117–138 A.D.) decreed that the child of a woman freed during pregnancy should be free, that a woman might make her will and that a free woman could inherit if she had children, or a freed woman if she had four, and that Carthaginian priests were to be crucified for sacrificing children to Moloch. He virtually abolished the *patria potestas* by deporting a father who had killed his son, and by compelling parents to rear their children instead of exposing them. The mutilation of exposed slave children in order to make them objects of charity was a great abuse of the time, and was justified by the philosophers as better than letting them die. But laws had now passed, as a "Perpetual Edict," into the hands of learned jurists and could no longer be changed by the caprices of emperors. Thus Justinian harks back to a rescript of Hadrian declaring the sale of children to be illicit and dishonest. Antoninus Pius (138–161 A.D.) gave to children the right to inherit from their parents and founded, in honor of the empress Faustina, the first institution for the protection of girls. This institution, which is commemorated in a Roman coin, was the first foundation designed to save female infants from destruction. Other endowments against infanticide grew apace. Marcus Aurelius (161–180 A.D.) abolished the paternal power of compelling the son to divorce his wife, and placed the alimentary institution of Antoninus Pius under the supervision of a praetorian of consular rank. These great benignant emperors were followed by a succession of bloody tyrants. Infanticide and exposure increased as poverty increased. Moved by the pleadings of Lactantius, Constantine issued an edict to all Italy and Roman Africa ordering that magistrates give immediate, necessary, and sufficient aid to indigent parents (May 12, 315 A.D.), and in order to save abandoned infants from death by exposure, declared all foundlings to be the slaves of those who chose to rear them, punished parents who exposed their offspring, and gave poor parents again the right to sell their new-born infants. The last edict bearing upon this subject before the fall of the Roman Empire was that of Valentinian, Valens and Gracian, punishing a parent for the exposure of his children (Payne).*

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* Payne, *op. cit.*, pp. 223–235.

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* Payne, *op. cit.*, pp. 236–256.

GREEK MEDICINE IN ROME

Of the Greek physicians after Hippocrates, those who are to our purpose—Aretæus, Soranus of Ephesus and Galen—came, not from Athens, Corinth or Thebes, but from Asia Minor. The only Roman contribution to medicine of importance is **Celsus,** which, as indicated by the researches of Max Wellmann, is a compilation or translation from many Greek sources, in particular of the Greek medical handbook compiled by Cassius Felix, the body physician to Tiberius Cæsar (*ante* 26 A.D.).

Celsus says that children are healthiest in spring and early summer, young people in winter. The diseases of infancy are apthæ, vomiting, night vigils, discharges from the ears and inflammation about the umbilicus; at teething, there are ulcerations of the canine gums, convulsions, slight fevers, diarrhea, particularly during eruption of the canine teeth. A little later, there may be glandular tumors, spinal curvature, struma, and painful warts (*achordonas*); at puberty, lengthy fevers and epistaxis. All children are in greatest danger up to the fortieth day, or in the seventh month, the seventh year, or at puberty. Infantile diseases, therefore, which do not disappear at puberty are apt to continue for a long time. Youth is most exposed to acute diseases, epilepsy, insanity and consumption, usually with hæmoptysis. A strong point made by Celsus is that "*children should not be treated as adults.*" Venesection, purgation and administration of wine should be avoided in weaklings, and care should be taken not to expose the child to wakefulness, hunger or thirst. In the pestilential fevers, cupping should be employed in children not strong enough to bear venesection, a light diet should be given, with enemata of water or a decoction of pounded barley. The anginas should be relieved by bloodletting, purgation, cupping about the throat, moist fomentations, gargles of hyssop, catmint, thyme, wormwood, bran or dried figs in hydromel, inunction of the palate with ox-gall or powdering it with pollen of pepper; finally, free incisions may be made at need under the mandibles, in the palate, about the uvula or in the sublingual veins. Aphthæ, when they spread from the gums to the palate, uvula and fauces, are apt to kill children. When they affect sucklings, the nurse should exercise her body, bathe frequently and foment the breasts with hot water; if the child has fever, she must diet and drink plenty of water, otherwise light wine; she must purge herself, if constipated, or procure emesis, if she has phlegm in her throat. The ulcers should be anointed with honey and Syrian rhus (sumach), or bitter almonds; or with dry rose leaves, pine kernels and small mint stalks incorporated with honey; or with mulberry juice boiled with equal parts of saffron, myrrh, alum, wine and honey, as gargles. If gargles fail, caustics (alum, chalcitis, copper sulphate) may be used with light diet. Cheese and honey cleans the ulcers. For discharges from the ears, puncture with a hot needle is recommended (VII, 8). In umbilical hernia,* avoid operation and employ fasting, purgation or an application of a mixture of hemlock, soot, washed ceruse, washed lead, two eggs and the juice of nightshade. This poultice should be kept on for a considerable while; in the diet, anything causing flatulence should be avoided. In infantile hydrocele, the tumor diminishes during fasting or a slight fever (VII, 18). In infantile hernia, the application of a bandage will often bring about reduction without recourse to the knife (VII, 20). Operations for phimosis and paraphimosis are described, also infibulation in boys "for preserving their voices" (VII, 25). The surgical treatment of varicocele (*ramex*) is also given (VII, 22).

The *De rerum natura* (I, 936–942) of Lucretius (98–55 B.C.) contains some admirable verses, showing how the Roman physician of the period smeared honey around the rim of a bowl to disguise the taste of wormwood administered to a child, a device which was doubtless derived from Greek practice.

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* Hernia, known to the ancient Romans as *crepatura* and *ruptura*, was first called by its present name in Martial and Arnobius (Hyrtl).

In the treatise on acute and chronic diseases of **Aretæus** the Cappadocian (2–3 Century A.D.), which, according to Max Wellmann, really derives from Archigenes (1st Century A.D.), diphtheria (*ulcera Syriaca sive Ægyptica*), pneumonia, epilepsy, cholera infantum, colic and other diseases affecting childhood are described in classic style. Tetanus in children is mentioned for the first time.

"Children are frequently attacked by it, but do not often die, because the affection is familiar and akin to them; striplings are less liable to suffer from it, but more readily die." Children usually suffer from aphthæ until puberty; "for children, in particular, have large and cold respiration, there is more heat in them, moreover they are intemperate in diet, have a longing for varied food and cold drink, and they bawl loudly both in anger and sport; and these diseases are familiar to girls until they have their menstrual purgation." Cholera attacks children frequently, but is not usually fatal. Ileus "is common in children who are subject to indigestion and they more readily escape from mischief, owing to their habits and the humidity of their intestines, for they are loose." Children with coughs, even youths, are apt to weather phthisis. In the young, stone usually form in the bladder; in the aged in the kidneys. Cachexia, jaundice and swelling of the spleen are common to childhood and youth, but are seldom fatal. "Children are subject to continued diarrhea, from an ephemeral intemperance of food, but in their case, the disease is not seated in the cavity of the stomach. Diarrhea attacks children and adolescents; dysentery, adults. Children are also subject to anasarca and leucophlegmata. The bad effects of gonorrhea in young persons are noted." Milk is the best remedy for marasmus and the induction of vomiting is beneficial in epilepsy.

The gynecological treatise of **Soranus** of Ephesus (2nd Century, A.D.) gives the most remarkable and complete account of pediatrics in antiquity.* It consists of 23 chapters dealing with the birth, washing, swathing, and nutrition of the infant, the choice and regimen of the nurse, the weaning of the child, teething, tonsillitis, aphthæ, skin eruptions and pruritus, catarrh and coughing, brain fever (meningitis?) and diarrhea. The salient characteristics of Soranus, which set him quite apart as a great physician, are a highly critical spirit, rational scepticism and scant reverence for the authority of the past.

If the new-born child is fit to survive, the mother must have been strong and healthy during pregnancy, the infant should cry and kick vigorously when laid down and should have no apparent bodily defects or abnormities. The cord should be severed, preferably with a sharp knife. and the stump ligated. The Germanic and Scythian custom of plunging the child in cold water after omphalotomy, in order to harden it or test its endurance, is strongly condemned, as also washing the child in brine, wine, or urine, or sprinkling it with powder of myrtles or nut galls. Even exposure to the air, for cooling, is bad. Salting the child is, however, still recommended. The crude Thessalian mode of swaddling recommended by Antigenes is condemned, and a rational routine is described at length, with special regard to gentleness of procedure. The barbarous Thracian and Macedonian custom of binding the child to a hard flat board is to be avoided, and a wooded pallet or a straw mattress, neither too hard nor too soft is to be chosen, with careful attention to the posture of the child. A clean, moderately warm room, avoidance of draughts and excess of light, and a mosquito netting for the infant's bed, are recommended. If the child shows no signs of hunger, it should receive no nourishment, but be moved about continually for the first two days. If it cries for food, honey, moderately stewed, is preferable to indigestible butter, abrotanum with butter, nasturtium or barley flour. Mother's milk is held to be valueless for the first twenty days, as being thick, cheesy and indigestible. Honey, sometimes mixed with goat's milk, is kept up for the first three days (sugar diarrhea), and the mother's breast must first be sucked by another infant before it is given to the new-born. If the mother's milk is not of the proper consistency, a professional wet-nurse is to be preferred. Soranus actually maintains that the mother should save her strength for future childbearing and that the child will thrive better on the milk of a stranger. His directions for the choice of a wet-nurse, her diet and mode of life, the testing of her milk, are given at great length and are similar to those of the Indian cult. The finger-nail test for consistency of the milk—whether it spreads gradually over the nail or a laurel-leaf, separating into drops on shaking, or flows thinly, or is viscous—and the water test, its preservation of its color in twice the amount of water, are here specified for the first time. Multiparæ are preferable as wet-nurses to primiparæ, on account of the inexperience of the latter, and large, robust, matronly nurses to small or attenuated. Greek nurses are recommended that the child may become early accustomed to "the most beautiful of all languages." Too much bathing, and bathing in hot water, debilitates the child. Bathing should be done in the day time, never at night, and then only after evacuation of the bowels or for skin rashes. The water should be warm, and the child accustomed, day by day, to colder baths. The directions for wiping, rubbing, salving and swathing are very minute. The subsequent suckling should be discreet and not excessive; the child must not be suckled every time it cries; other causes than hunger should be sought, if it cries continually. The child should not be rocked or otherwise shaken up after breast-feeding, as the effect is like that of sea-sickness. The swaddling clothes may be gradually removed in 40–60 days after birth. If the child tries to sit up or stand, it should be supported to avoid deformation of the spine or lower limbs. Soranus notes that these matters were neglected by the Roman dames, who lacked the warmth of sympathy with children which Greek women possessed. Soranus' observation of the frequency of crooked limbs in Roman children is regarded by Wilhelm Ebstein as evidence of infantile rickets in antiquity.* The child should not be weaned, for any reason, until it is strong enough to take solid food, usually not less than six months after birth. Then bread crumbs, softened in honey-water, milk, sweet wine or honey-wine may be given. Thereupon a soup of coarsely ground husked wheat, a thin brew and soft-boiled eggs may be tried, but no milk should be given during this repast, as the mixture is indigestible. Thirst should be allayed by water or thinly diluted wine, given by an artificial nipple. Nothing to be chewed should be given at first, and the addition of roots, poppy-seeds and sesame should be avoided. Complete weaning should come to pass at the eruption of the teeth, that is 1½–2 years after birth. Abrupt weaning by means of bitter or malodorous applications to the breasts is bad for the infantile stomach. Spring is the best time for weaning, autumn the worst, on account of its uneven temperature. The view of Mnesitheus and Aristanax that girls should be weaned six months later than boys is condemned, since girls are not weaker, as these writers maintain, but of stronger and fuller habit of body than boys. The child must be early accustomed to all good food staples after weaning, but if too fat, its diet must be restricted, and if it is gluttonous, this must be accomplished by diverting its attention with play. If it tends to reject food, its appetite must be whetted by variety. In sickness after weaning, milk diet must be resumed until health is restored. Teething sets in about the seventh month, and then irritation of the gums by chewing must be avoided. Before teething, the gums should be gently rubbed with oil or fats, and the child may be permitted to suck fat bacon without swallowing it, but this should cease when the teeth appear. The gums should not be irritated by butter or acid substances, and if there is much inflammation, poulticing and sponging are recommended. In tonsillitis, honey water and barley brew may be introduced, and all sources of congestion, such as the custom of turning the child upside down seven times, are pernicious. In aphthæ, the mouth may be anointed with honey, in mild cases, or with moist astringent applications (lentils and pomegranates) where the mouth is hot and dry; internally, fresh or pressed rose-leaves or cyprus or tamarisks. Mouth-washes of mulberries, poppies and plantains in honey, iris salves with honey, or any astringent decoction cooked in honey, or powders of rose-leaves, saffron, myrrh, nut-galls, juniper, moistened with honey, or any of these mixtures with the juice of sweet pomegranates are recommended. Removal of the scurf with the finger, a custom of Syrian nurses, is bad practice. Pruritus is treated by fomentations and applications of oily salves, with a slight admixture of wax, that they may cling to the body; skin rashes and ulcers should never be treated with salt water or urine; they should be let alone until it is necessary to apply decoctions of roses or lentils or astringent applications of myrtle, mastix, blackberries or pomegranates, etc. Inflamed ulcers after evacuation of pus are treated by similar applications. Irritating remedies are to be avoided in catarrh and coughs; honey may be trickled into the mouth or the phlegm evacuated by inducing vomiting; in attacks of coughing, dainties such as pine-kernels, roasted almonds, linseed, licorice, gouts' thorn and honey are best, and bathing is interdicted. Siriasis, an inflammation of the brain and its membranes, with sunken fontanelles, sunken eyes, pallor, dryness and loss of appetite, is treated by applying to the temples a mixture of rose oil and yolk of egg, or of heliotrope leaves, pumpkin chopped fine, cucumber rind, or of rose oil and nightshade juice. Infantile diarrhea is treated by injecting plantain juice with an aural syringe, or if the child is still taking the breast, by giving astringents to the nurse; constipation by giving laxatives to the nurse. If the child has been weaned, the same remedies may be given directly. Atresia ani is remedied by dilatation with the finger or by perforation.

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* For a German translation of which, see "Die Gynäkologie (περὶ γυναικείων) des Soranus von Ephesus," übersetzt von H. Lüneberg, Munich, J. F. Lehmann (1914), pp. 56–92.

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* W. Ebstein. Virchow's Arch., Berlin, cxciii (1908), pp. 522–524. Ebstein speaks (p. 520) of an infantile skeleton of the end of the 1st Century A.D. (just before Soranus), excavated at Centirupe and now in the Museum at Syracuse, showing indubitable signs of infantile rickets.

The *Noctes Atticae* of Aulus Gellius (2nd century A.D.), known to Latinists as a repository of curious facts about antiquity, contains some striking passages about the care of infants, in which the ideas of Soranus about breast-feeding are reflected.

Galen (131–201 A.D.) gives a long series of controversies on the viability of the seven- and eight-months child, with much admixture of astrology; opposes the German and Scythian custom of immersing the newborn in cold water for purpose of hardening; indulges in much casuistry about infant nutrition, warns against nursing the child before its bath or during the bath, and is generally at one with Soranus in regard to the regimen of infant-life.

He mentions congenital atresia of the urethra, recommends a plaster bandage for paraphimosis, defines hydrocele, hermaphroditism, hydrocephalus, exomphalos (prominent umbilicus), epiploomphalos (omental prolapse into the umbilicus), enteromphalos (intestinal prolapse) and hydromphalos (water in the umbilicus); gives directions for the physical and mental regimen of epileptic children; describes white, red and black aphthæ, differentiates between round worms, ascarides, and tenia, and recommends verbena (*heria*) and helenium for ascarides; he mentions the frequency of hiccough in children and ascribes it to the "corruption" of too solid food in the body from overeating or to catching cold; he defines three kinds of intermittent fevers, *viz.*, the quotidian (from putrid phlegm), the tertian (from excess of yellow bile), and quartan (from excess of black bile) and regards the quotidian as peculiar to children. He describes asthma, in connection with goitre, as a painless glandular (thymus) swelling peculiar to the neck. In his treatise *De morborum causis* (ed. Kühn, 1824, VII, 27), Galen gives an account of infantile rickets.*

Caelius Aurelianus (5th Century A.D.) is, apart from Celsus, the only Roman writer who contributed anything of note to pediatrics.

He regards epilepsy as a *passio puerilis*, frequently associated with teething thus confusing it with infantile convulsions. For treatment, the child is covered with a cloth and warmed by rubbing with oil, while honey is sparingly trickled into its mouth, and goat's milk is given if the child cannot take the breast. If it can suckle, the breast is smeared with honey. The child should be carefully guarded against fright, irritation and excitement, and if the nurse is epileptic, she must be discharged. He describes an "ignis sacer" covering the neck and chest in inflammatory angina, which was probably scarlatina (Kroner). He gives a good account of the symptoms of intestinal worms. The child groans in its sleep, rolls about, gnashes its teeth, tends to lie prone, cries out suddenly, or falls silent, is seized with convulsions, sometimes becomes somnolent, the face becomes emaciated and loses its color; the child gets cold and answers questions with difficulty; sometimes throws itself about with outstretched hands, working itself into perspiration. The worms may even be felt in the thinnest parts of the intestines. The pulse, as Themison says, is irregular and often deficient. The worms sometimes come out of the nose and mouth, as well as the rectum. To remove them, three or four pills the size of a bean in warm water, or "chamelaeæ" rubbed in honey-wine are recommended. Asthma is described as a disease peculiar to children and old people, more frequent in the weak than in the strong, occurring oftener at night than by day, in winter than in summer with a feeling of suffocation, hissing respiration and lividity of the lips.†

BYZANTIUM

(476–732 A.D.)

The rôle of Byzantium in the history of medicine was that of an embalming medium or cold storage plant for the accumulated knowledge of the past. Byzantium was, in Allbutt's phrase, a citadel of "culture," with all the untoward associations which have latterly attached to the term. Church and State were supreme, upheld by laws as rigid as the grip of a vice. An absolutist theory of existence prevailed, with definite aversion to freedom of thought and action. The adjective "Byzantine" connotes architecture of wonderfully massive, ornate type, splendor of raiment, decoration and creature comforts, abounding luxury, licentiousness and with it, an effemination or eviration of character, which, in the end, made the population of the great city powerless to protect themselves from invasion. People were probably no worse then than they are now in overcrowded communities, but their life-lines were mapped out for them in advance, and virtue, knowledge and talent were as nothing in the scale with consistent subservience to authority. In the many histories of

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* Delpeuch, Presse méd., Paris (1900), p. 383. W. Ebstein, Virchow's Arch., Berlin, cxciii (1908), pp. 524–528.

† For an exhaustive study of Greek pediatrics, arranged by diseases, see T. Kroner, Jahrb. f. Kinderheilk., Leipzig, N. Y., x (1876), p. 340; xi (1877), p. 83; 236.

Byzantium, we hear little of the children, except that "their education tended to keep them all in a definite groove" (Finlay). "In place of Augustus," says Allbutt,

> "came a kind of Sultan, wearing that oriental diadem, the mere dread of which had brought Caesar to his end; the Emperor was approached with adoration as a living god, and lawyers buttressed his throne with an absolutist theory of the constitution which was universally accepted. . . . But the price was a heavy one; the heirlooms of the past were carried into fortress, and for a millenium were immured in a sumptuous, almost a spellbound treasure house. The calcareous shell was of mother of pearl; the walls and towers of the casket shone in the sun with such splendor as Jeremy Taylor conceived of the Kingdom of Heaven. Exalted in the wilderness of Europe, shining like a sun, radiant with gold and gems, pompous with priests and men of war, Byzantium guarded the precious germs of which a new world was in due time to be born. But meanwhile this very pomp which, to the hordes which beset it, made it seem invulnerable, stiffened the sinews of the defenders. In their serried regiment there was no play for personal freedom, no play for varieties of temperament or diversities of creed. A rigid uniformity of array, an absolute subordination of rank to rank, an unbending orthodoxy of belief were the cement of the fortress, the conditions of its solidity and immunity, and the protection of its sacred store. We shall anticipate, then, that within its walls there would be no expansion, no breathing of the human spirit, but the immobility of a great rock, the silent watch of its sentinels, the enslavement of the poor and the needy, and the bondage of the human mind . . . Heresies were persecuted not as religious but as political perils. Unfortunately in this, as in too many other periods in the world's history, machinery, when it has served its purpose, is not scrapped in due time, but endures to the stifling of young ideas and the bondage of young limbs."*

The Byzantine Empire lasted until 1453, surviving even the invention of printing, but it never attained to the multiform life of the later Middle Ages. As Hirschberg says, it merely went on marking time in the past.

Among the later Greek and Roman writers, beginning with Galen and Celsus, there had arisen a custom which was to be the fashion in medical literature for over a thousand years, namely the attempt to summarize all extant medical knowledge into one massive treatise. This was to be as characteristic of Bartholomæus *Anglicus* as of Pliny, of Niccoló Falcucci as of Galen or Avicenna. Of the great compilers of Byzantium, only three need concern us, Oribasius (325–403 A.D.), Aetius of Amida (6th Century, A.D.) and Paul of Ægina (625–690 A.D.). The works of these men are wonderful and even fascinating summaries of the medical writings of antiquity. Their pediatric lore is considerable.

Oribasius (325–403 A.D.) gives Aristotle's lost observations on the eight-month's child, and long chapters (Daremberg's Oribasius, III, 117–182) on the rearing of infants, the choice of a nurse, the quality of milk, the education of a child up to 14 and after, and the regimen of childhood according to Mnesitheus, Rufus of Ephesus, Athenæus and Diocles.

He cites the recipe of Mnesitheus for "rheuma of the brain" (cold in the head): Do not anoint with honey, but bathe the child in a warm bath, pouring hot water on its head, and making it eat much honey; then induce vomiting by tickling the throat, in order to void the phlegm. Meat is bad for infants, also thick soups, as creating phlegm. Honey is the natural first food: its sweetness is attractive and it purges the intestines of meconium (Rufus of Ephesus). It is very bad for the nurse to eat celery, mint, or garlic, as affecting the milk and inducing epilepsy and pustules in the child. Children born thin are apt to take on flesh because they need it, while those born fat, with rosy cheeks, usually get thin later, because puffy children need evacuation. Never frighten infants, as it may lead to infantile convulsions or epilepsy. Never bleed children under 14. Congenital hypospadias, with the urethal opening in the lower surface, also epispadias, are described at length, with surgical treatment. Antyllus' account of phimosis, paraphimosis, and dislocated phimosis is preserved in Oribasius. Three varieties of hydrocephalus (between the skin and pericranium, between pericranium and cranium, between cranium and the cerebral membranes) are described in great detail. The observations of Galen and Archigenes on white, red and black aphthæ and their frequency in Egypt recur in the Byzantine compilation, and erysipelas is again mentioned. Skin eruptions from perspiration and other causes are enumerated among children's diseases and are also ascribed to unwholesome milk or contagion from the maternal parts at birth. Diaphoretic remedies are prescribed for the wet-nurse. The directions for the education of children in Oribasius are refreshingly modern in spirit. In the seventh or eighth year boys and girls should be confined to genial, humane tutors, whose encouraging praise and pleasant flow of language will inspire them to excel. A generous diet, too, must not be forgotten (modern school-lunches for children). Bitterly censorious teachers who obstinately uphold their authority everywhere, will only make slavish, cringing, fearful pupils, disgusting them with the objects of instruction. How can it be otherwise, he says, when the child, which loses its presence of mind when beaten, is yet required to learn and memorize what it learns? Children who are tormented with instruction all day, and not allowed to play, are in exactly the same class with servants, who break down from unintermitting labor without recreation. At twelve, languages and the mathematics should be begun, with bodily exercise under experienced instructors, who know the right measure and the right time for eating, gymnastics, bathing and sleep. Most people will engage thoughtful or experienced men to look after their stables, at a liberal salary, while they entrust their children to inexperienced teachers, usually ignorant persons who have already failed in life.

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* Sir T. C. Allbutt, Byzantine Medicine (Finlayson Lecture), Glasgow Med. Jour., lxxx (1913), 4 s., p. 323.

There is much sound pediatrics in the huge "Tetrabiblion" of **Aetius** of Amida, who was royal physician to Justinian I (527–565 A.D.) and lord high chamberlain at the Byzantine Court.

Lingual adhesion is described as a common abnormity, with semeiology; the acquired form is usually due to hard sublingual ulcers and cicatrices. Movement of the tongue and sucking the breast are difficult, speech comes late, and words containing the letters R, L and K are difficult to pronounce. An operation for severing the frenulum is given. Ranula (*ranunculus*) is described as a sublingual tumor, usually affecting the veins. Acquired umbilical hernia, from distension of the abdomen by faulty diet and flatulent colic, is clearly recognized. The symptoms of tonsillitis are: marked fever, difficult swallowing, constipation, increase of pain in the evening, pain in the ears, difficult breathing. Gargles, liquid and semi-solid foods and blood-letting are prescribed, and, if there is suppuration, an Egyptian salve of resin with turpentine, honey and sweet oil. There is some evidence that Aetius knew of the scarlatinal anginas. Incontinence of urine is differentiated as either continual and dribbling or occasional and nocturnal. The former is attributed to paralysis of the sphincter of the bladder. Drinking water in the evening and irritating applications to the parts are forbidden. Hiccough, from hasty suckling or from cold by wetting the clothes, is treated by caraway seed, acidum scyllinium, holding the breath, production of sneezing, elevating the extremities and bringing them together, and cold. Otitis is treated by trickling in albumen mixed with human milk; aural discharges by irrigating the ear with alum and wine and plugging it with soft wool. Eczemata are defined as painful, non-purulent pustules, resulting from heat and perspiration. Herpes is ascribed to accumulation of yellow bile in the locality affected. If it collects in quantity with ulceration of the whole skin, it is "herpes exedens."

Alexander Trallianus (525–606) left a treatise on intestinal worms, which was translated into Latin by Hieronymus Mercurialis (Venice, 1570) and subsequently incorporated in his pediatric treatise (1583).

Paul of Ægina (625–690), the last of the great Byzantine compilers, begins his Epitome with a series of compact chapters on the complaints of pregnancy, the wet-nurse, the milk, how to correct bad qualities of milk, the management of infancy, infantile eruptions, cough and defluxion, pruritus, dentition, aphthæ, excoriations of the thighs, discharges from the ears, siriasis, the regimen of childhood and youth, exercise, the kinds of friction, vociferation or exercise of the voice, constriction of the skin and lassitude. Whoever wishes to gain a bird's eye view of pediatrics from classical antiquity to the late Renaissance period, will do well to read these terse chapters in the English version of Francis Adams of Banchory, with his scholarly and illuminating commentaries. Much of the Pauline pediatrics is taken from Oribasius, going back from Oribasius to Galen, Soranus, and their predecessors, while the same material was copied and carried forward in a monotonous, almost mechanical, way by Rhazes, Haly Abbas, Avicenna, Bagellardo, Metlinger and the later Renaissance writers. Oribasius and Paul are, in fact, half-way houses between remote antiquity and such pediatrists of newer stamp, as Walter Harris or Underwood. The old thumb-nail and rennet tests for nurses' milk, for instance, which originated with Soranus, were passed on by Oribasius and Paul to author after author, long after Soranus and the Byzantines, who cribbed his material, had been forgotten. The vegetable remedies for infantile disorders proposed by Oribasius and Paul were enormously multiplied, for each disease, by the drug-fancies of the Arabian physicians.

Paul describes ranula (ranunculus) as an inflammatory sub-lingual tumor, usually occurring in childhood (III, 26). To Soranus' treatment of imperforate anus, he adds excision of the occluding membrane with the scalpel, irrigating the wound with wine (a common procedure in the mediæval treatment of wounds). Atresia of the pudenda, atresia vaginæ and imperforate hymen are clearly differentiated (VI, 72), with directions for exploration with an instrument, incision or excision with a fistula-scalpel, and plugging of the vagina with a tent of charpie. Three kinds of hermaphrodism (after Leonides) are noted in males, and one in females (IX, 69). In the extensive chapter on ophthalmology, congenital strabismus is described for the first time as a spasmodic affection of the muscles moving the eye (III, 22). The squint is remedied by a visor-mask, compelling the child to look straight forward. This was afterward figured in the illustrated ophthalmological treatise of George Bartisch (Dresden, 1583). A lamp is placed opposite the mask, so as not to shine obliquely; then the eye is turned to the nose; purple flocks of wool should be fastened to the outer angle of one eye, so that by looking at them steadily, the patients may correct the state of vision." Eczemata and impetigo in children are mentioned (IV, 3) and an attempt is made to differentiate between the splotches of leprosy and those of psoriasis.

In the Byzantine Period, the early Fathers of the Christian Church concerned themselves not a little with medicine. Tertullian surpassed all others in his scientific and medical knowledge. (Harnack).

In support of the Christian doctrine that even the unborn child is endowed with a soul, he speaks of the "unconscious intelligence" of climbing plants, and maintains that even the crying of the child shows its consciousness of birth into life. "It recognizes mother, nurse and wet-nurse by their breasts, rejects an unfamiliar breast, dislikes a strange bed, and will only go to persons whom it knows." Development depends upon environment and education. Dull, stupid people come out of Thebes, the Athenians are the cleverest in thought and speech, and in the precinct of Colyttus, where Plato was born, children learn to speak a month earlier than is usual. The soul originates with generation of the fœtal body, as pregnant women know, for still-born children are evidence that life was once in them. In this doctrine, the soul is actually generated at impregnation and unfolds itself at puberty, an argument which was the mainstay of Christian antagonism to abortion and infanticide. Craniotomy and dismemberment of the fetus to save the mother's life are attacked for the first time in the writings of Tertullian. Eusebius (302 A.D.), Gregory of Tours (581) and Marius, Bishop of Avenches (570) described epidemics of small-pox, which was first called *variola* by Marius. Diphtheria is called "*esquinancie*" (*cynanche*) in the Chronicle of St. Denis (580), and Roman epidemics of 856 and 1004 were described by Baronius, and, in Byzantium (1039) by Cedrenus. In the 5th century, A.D., the German barbarians designated crooked limbs as "*krump*," and humped backs as "*hover;*" the Anglo-Saxons called the rhachitic pigeon-breast "the sharp bone" (*scearpan banum*) and the narrow chest "*angbreast*" (Heyne; Höfler).*

ISLAM

(732–1096 A.D.)

In the Byzantine civilization, we see a rigid scheme of political dogma imposed upon an isolated community for an extraordinary period of time. In the Mohammedan world, we see the same thing distributed down to the present time over the widest area of space. Whether in Egypt or India, Bosnia or Persia, Islam remains the same. Fatalism and resigned submission to authority characterize the Mohammedan faith, and like the Greeks and the Romans in classical antiquity, the Moslem sees epidemic diseases as scourges of God and is ignorant of the fact of contagion. A rigid conservatism prevented him from grasping the larger problems of public hygiene, and what progress he made in the sanitation of private life was due to the wise teachings of the Prophet, and to the native ingenuity of the Moslem chemists and craftsmen. To Mohammed was due the interdiction of female infanticide (Koran, XVI, 60–61) and the state care of foundlings. The pagan Arabs of the pre-Islamitic period buried their daughters alive.

The **Koran**† prescribes that mothers shall suckle their children for two full years (II, 233), or that the total period of pregnancy and lactation up to weaning shall be thirty months (XLVI, 14). If the mother is unable to suckle her child a wet-nurse may be employed (LXV, 6). In the Koran, the stratagem mentioned in Exodus (II, 1–9), whereby the aunt of Moses secured his mother as a wet-nurse, has the *variant* that Egyptian wet-nurses were first offered and rejected (XXVIII, 11), which Opitz interprets as meaning that Mohammed believed that maternal milk strengthens the racial characteristics in a child. These are the only pediatric items in the Koran, a book in which honey is specified as the sole and universal human remedy (XVI, 71).* The rest of Arabic custom in regard to the care of infancy is preserved in the Mohammedan books of ethics as handed down by tradition. At birth, the child is washed, swathed and carried by the chief *malawi* to a gathering of male relatives who chant the *azan* and the *iquamah* (calls to prayer) in the child's left ear, as the Prophet is said to have done to his grandson Hassan. Following another action of Mohammed's, the *malawi* then chews a bit of date-fruit and puts it in the child's mouth. Alms are then distributed, in weight equal to the weight of the infant's hair, shorn for this purpose, and verses from the first chapter of the Koran are recited for the health and prosperity of the child. The friends and neighbors then visit the home with presents and congratulations. The infant is named on the seventh day, usually after the Prophet, his followers or relatives, or some member of the child's family. On the same day is observed Mohammed's ceremony of the *aqiqah*, that is the sacrifice to God in the name of the child of two young unblemished he-goats in the case of a boy, or one he-goat for a girl. The animals are dressed and cooked, and, as the friends partake, they pray as follows:

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* Moriz Heyne: "Körperpflege und Kleider bei den Deutschen von den ältesten geschichtlichen Zeiten, etc.., Leipzig (1903), p. 22. M. Höfler, Altgermanische Heilkunde (Puschmann, Handbuch der Geschichte der Medizin, Jena, i (1902), p. 476). Cited by W. Ebstein, *op. cit.*, pp. 528–529.

† See T. P. Hughes, "A Dictionary of Islam." London (1885), pp. 50–53.

"O God! I offer to thee, instead of mine own offspring, life for life, blood for blood, head for head, bone for bone, hair for hair, skin for skin, in the name of the great God, I do sacrifice this goat."

This ritual of substituting a scapegoat for the sacrifice of the child itself is enjoined by Mohammedan law and observed in all parts of Islam. On the fortieth day, the mother is purified and is then free to go about as usual. On this day the child is placed in a swinging cradle. If a wet-nurse is employed, she must be a woman of well-balanced temperament, since her traits are apt to be communicated to the child. As soon as a boy can talk, he is taught the opening phrase of the Koran (*Bismillah*). He is then sent to school to learn the alphabet and to recite certain chapters of the Koran. The memorizing of the whole of the Koran completes his religious education. To this are added the ordinary rules of arithmetic. Schools are very numerous in the Mohammedan world. Sir Richard Burton said that "Islam orders a school to be built by whoever erects a mosque." Circumcision (*khitan*) is not mentioned anywhere in the Koran, but it is held to be *sunnah* (necessary and proper), and according to the tradition of the Prophet, who was assumed to have been circumcised. It is usually done in the seventh year, but it is lawful that it be done on the seventh day after birth or at any time between the seventh and twelfth years. The rite is usually performed by a barber and consists in drawing the prepuce tightly forward with a bamboo forceps, causing great momentary pain, which is swiftly terminated by a brisk downward stroke of the knife. The hemorrhage is checked with burnt rags and ashes. In Egypt, the rite is preceded by an elaborate street-parade and ceremonial (Lane). Puberty is established by the inception of virility and menstruation, and is declarable at 15 in both sexes. The Mohammedan theory of life is that a boy should be educated as soon as he is weaned, taught gravity and decorum by extreme respect for his parents and the society of his elders, inured to hardship and contempt for luxury, set to employment he is best qualified for (vocational aptitude being often determined by horoscope), and married as soon as he is established in the world. The training is stoical, designed to make warrior-gentlemen. The only objects of food, worldly possessions, sleep, etc., are the maintenance of health. Food and drink are held to be medicine for the cure of hunger and thirst and are to be as sparingly used as drugs. Delicacies and a varied diet are scorned. Subsistence upon a single dish or upon dry bread is held to fit a man for hard times.

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* K. Opitz, "Die Medizin im Koran." Stuttgart (1906), pp. 15–16.

Little meat is eaten and liquids are not drunk at table. Physical hardening is attained by intensive exercise. To sleep by day is despicable. Strong drink, sweetmeats and unusual creature comforts are forbidden. Wealth and luxury are despised as diminishing the capacity to endure the desert, if necessary. The attainment of an elegant dignified style of manners is a worthy ambition. Actions are open and above board, lest they be culpable, and a child is trained to silence. The seven deadly sins of Islam are "disobedience to parents, idolatry, murder, falsely accusing modest women of adultery, wasting the property of orphans, usury, and desertion of an expedition against infidels." The grave decorous attitude of the boy toward his parents fits him, as Lane says, for an abrupt introduction into the world, and for society.* Sir Richard Burton,† however, found the children at Medina, like the *enfants terribles* of India, "a nursery of madlings, pulling to pieces everything they could lay their hands upon, and using language that would have alarmed an old man-of-war's-man." He says that "parents and full-grown men amuse themselves with grossly abusing children, almost as soon as they can speak, in order to excite their rage and to judge of their dispositions." The object is to temper them for life. Punishments are often in the nature of tongue-lashing, and, in corporal punishment, blows are short, sharp, decisive and few in number, lest punishment lose its power. Girls do not learn to read or write, but are brought up in rigid seclusion and taught only domestic matters. Burton, in his "Notes on Waitz's Anthropology," says of the Oriental policy of seclusion: "The Muslimah is certainly guarded from temptation; and when she falls into it she is deservedly punished. The Christian woman is exposed to every risk, and placed upon a comfortless eminence, that publicity may deter her from yielding."‡ Although the tales of Aladdin and Sinbad have delighted the children of civilized humanity for centuries, the entire Arabian Nights contain only two references bearing upon our subject, *viz.*, that Arab infants are commonly carried astride the nurse's hip or shoulder and that the expression "child of the nurse" implies that an individual has been delicately reared (Burton).

The pediatric literature of Islam is meagre and far inferior to that of Byzantium. Rhazes, Avicenna and Haly Abbas, in fact, took much of their pediatrics from Oribasius and Paul of Ægina. Appended to the ten books of **Rhazes** (869–962) "*ad Almansorem*" is a brief pediatric treatise (*De ægritundinibus puerorum et earum cura*) in 24 chapters, each descriptive of a separate disease. This treatise was liberally copied by Avicenna, Bagellardo and the subsequent authors.

The chapters deal with an impetigo-like head eruption (*sahafati*), a favus variety of the same (*favositas puerorum*), hydrocephalus, tympanites (inflated abdomen), sneezing (coryza), wakefulness, epilepsy, indigestion, aural discharges, purulent otitis (*de veneno fluente de auro*), diseases of the eyes (conjunctivitis), infantile strabismus (*de obliquitate visus*), disease of the teeth, aphthæ, vomiting, diarrhea, constipation, cough, pruritus and rashes, intestinal worms, umbilical hernia, fissure (*de crepatura*), vesical calculus, and relaxation and spasticity of the limbs and body (*siphac*).§ The merit which these individual chapters possess over other clinical paragraphs of the same kind, for a long time before and after, is that the semeiology of each disorder is clearly stated, as far as the author's knowledge goes, that where etiological reasoning is attempted, a simple common-sense cause (such as *corruptio lactis*) is assigned, with little reference to humoralism. The treatment, while mainly herbal, is usually plain and simple with a little touch of superstition here and there. Rhazes notes the yellow stools and griping pains in infantile diarrhea (*albedo in egestione et tortio in ventre*), and recommends the application of an *emplastrum constipans* to the abdomen. For insomnia, oil of violets in vinegar or oleum anetinum with lettuce juice are put in the child's nostrils, and, of course, it is allowed to suck syrup of poppies, while the temples and forehead are bathed with oil of opium and crocus. In epilepsy, the diet is to be regulated, the nurse purged; the child is given only what milk it can digest; it is given asafœtida to smell, and (a remnant of the cult of Apollo) a peony is suspended around its neck and an emerald attached to its feet. Poppies, among other simples, are exhibited in cough. In vesical calculus, the strangury, tenuous stream of urine, great pain and penile pruritus are noted. The prescriptions for syrups, electuaries, plasters, etc., are written in modern style, with the Arabic symbols.

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* Lane, Modern Egyptians.

† Sir R. F. Burton, "Pilgrimage to Al-Medinah and Meccah," London, ii (1893), pp. 292–293.

‡ Burton: Anthrop. Rev., London, ii (1864), p. 249.

§ *Siphac*, according to Hyrtl, is a generic term for membrane or skin. Rhazes' definition of "relaxation" reads like a foreshadowing of infantile paralysis: "Relaxatio accidit pueris vel *in uno membro* vel toto corpore et prohibet ipsum ab ambulatione et motu; provenit propter viscosum humorem *relaxantem nervos*" (Cap. XXIV).

The treatise on smallpox and measles of Rhazes, translated into English by W. A. Greenhill (1848), is perhaps the most remarkable contribution to internal medicine between Hippocrates and Sydenham.

After making the usual obeisance to Galen, who has vague references to smallpox, Rhazes notes the frequency of the disease in children, and gives a most minute account of the semeiology, differentiating it from measles; the mild and fatal varieties of both diseases are carefully defined; the dangers to the eyes, ears, nose, throat and joints are accentuated in a special chapter; the prevention and treatment are detailed at great length, *viz.*, cupping in sucklings, venesection after 14, the diet "such as extinguishes heat," snow-water and other cooling drinks, acid fruits, cold baths, etc., warm compresses, to accelerate the eruption; with special treatment for the eruption and the scars.

According to Hennig, Rhazes held that cheese causes calculi and overfeeding scrofula. He showed that the urachus lies in the umbilical cord.

The "Canon" of **Avicenna** (980–1036) contains (Lib. I, Fen. 3) four chapters on the hygiene of newborn infants, the regimen of the diseases of infancy and the hygiene of childhood, followed by 19 chapters on the hygiene of adolescence, including exercise, bathing, diet, sleep, and the overcoming of lassitude.

After the usual directions for bathing and swathing the child and the selection of a wet-nurse, the following diseases are mentioned in remarkable terse fashion, with neither definition nor semeiology, but a considerable amount of dry detail as to treatment: vomiting, abscesses (*apostemata*) in the gums and mouth during dentition, tetanus, cough, rheumatism, aphthæ, otitis media, meningitis and cerebral abscess, hydrocephalus, conjunctivitis, cataract (*albedo in pupillis*), fevers, coryza, pustules on the body, tumors in the groin, umbilical abscess, sleeplessness, hiccough, vomiting, weak stomach (*stomachi debilitas*), terrifying dreams, abscess in the throat, stertorous breathing in sleep, tympanites (*ventris inflatio*), hernia, tenesmus, worms and abrasion of the hip (femoral intertrigo). The subject mtter is obviously derived from Rhazes, with a few extra therapeutic wrinkles. In the chapters on childhood and adolescence, the child is to be guarded against excesses of temper and low spirits and if its sleep is restless, alternate playing and feeding are recommended. At six, when the child's instruction begins, it should be allowed to learn gradually and not be driven, and there must be more exercise before eating and less bathing. Wine is interdicted, as a cause of congestion, choler and frequent urination. Exercise is treated at great length.

Avicenna described anthrax (Persian fire) the Guinea worm (*Vena medinensis*), recognized the sweetish taste of diabetic urine (known also to the Hindus) and standardized the irrigation of wounds with wine for the entire Middle Ages. The Juntine editions of 1595 and 1608 contain striking plates of the Hippocratic method of treating spinal deformities by forcible reduction, reintroduced by Calot in 1896.

Ali ben Abbas or **Haly Abbas** (–994 A.D.) maintains that male infants are born heavier than females, mentions a case of superfetation, recommends treating atresia ani with the finger or phlebotome, and in his "Liber Regius" (I, IX, Chap. 63, I, 19–22) gives some details about the diseases of infancy (Hennig).

The surgical treatise of **Albucasis** (11th Century) contains chapters on the operative treatment of infantile hydrocephalus (Chap. 1), the extraction of teeth (Bk. II, Chap. 30), the treatment of congenital imperforate urethra (Chap. 55), the repairing of effects of malpractice in circumcision (Chap. 57), the treatment of imperforate anus (Chap. 79).

THE MIDDLE AGES

In the Middle Ages, the power of imperial Rome did not end with the downfall of the Roman Empire, but was modified by the teachings of Christianity, and for over a thousand years the great city continued to be a world-center under the sway of the Roman Catholic Church. The utterances of Christ himself about children, the Latin hymns of Ambrosius, St. Augustine's account of his boyhood, and the many figurations of the Madonna and the Christ-child in oil painting, majolica and terra cotta are all eloquent of an entirely new feeling toward childhood and parenthood. Through the influence of Christianity, **edicts against infanticide** and the selling of children into slavery were issued by the Roman emperors Constantine (315, 321), Valentinian, Valens and Gratian (374), Valentinian, Theodosius and Arcadius (391) Honorius and Theodosius (409), Theodosius II (438), Valentinian III (451), but beginning with Barnabas, a contemporary of the Apostles, the founders of Christianity had, long before this period, established the fact that infanticide, by exposure or otherwise, is a heinous crime. In a long series of bold, vigorous pronouncements addressed directly to the people, the fathers of the Church denounced infanticide and abortion, in the manner of the Hebrew prophets.* The belief that even the unborn child has a "soul" did much to obliterate these practices.†

The sentiment goes back to a passage in a letter attributed by Origen to Barnabas, a contemporary of the Apostles: "Thou shalt not slay the child by procuring abortion, nor again shalt thou destroy it after it is born." Justin Martyr (2nd Century A.D.) said that

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* For the Latin texts, see J. F. Terme and J. B. Monfalcon: "Histoire des enfants trouvés," Paris (1840), pp. 69–74; and the effective summary of Payne, *op. cit.*, pp. 257–271.

† Lecky, "History of European Morals," New York, ii (1869), pp. 34–36.

"to expose newly born children is the part of wicked men"; and, with equal force, he stigmatized the sin of rearing girls only for the trade of prostitution. His feeling about marriage ("If we marry, it is only that we bring up children") is at one with that of Virchow ("*Man schliesst doch keine Ehe um kinderlos zu bleiben*"). Tertullian (200 A.D.) made bold to address the sovereign power of Rome itself in the following language: "Rulers of the Roman Empire, seated for the administration of justice on your lofty tribunal—you first of all expose your children, that they may be taken up by any compassionate passer-by," and addressing the people themselves, he says: "Although you are forbidden by the laws to slay new-born infants, it so happens that no laws are evaded with more impunity or greater safety, with the knowledge of the public and the suffrage of this entire age." Clement of Alexandria (–220 A.D.) said: "Man is more cruel to his offspring than animals." Minucius Felix (2nd Century A.D.), a Roman lawyer converted to Christianity, attributed the practice of infanticide to the callous pagan trait of delight in bloody sacrifice, and likened those who followed it to aboriginal Saturn, who devoured his own offspring. Lactantius (4th Century A.D.) said that to strangle newborn children is the greatest impiety, "for God breathes into their souls for life, not for death." And again, he says: "It is as wicked to expose as it is to kill." Basil the Great (330–379 A.D.) and Ambrosius (340–397 A.D.) fulminated against the sale of free children to gratify the avarice of their parents' creditors. The exhortations of the Fathers were,

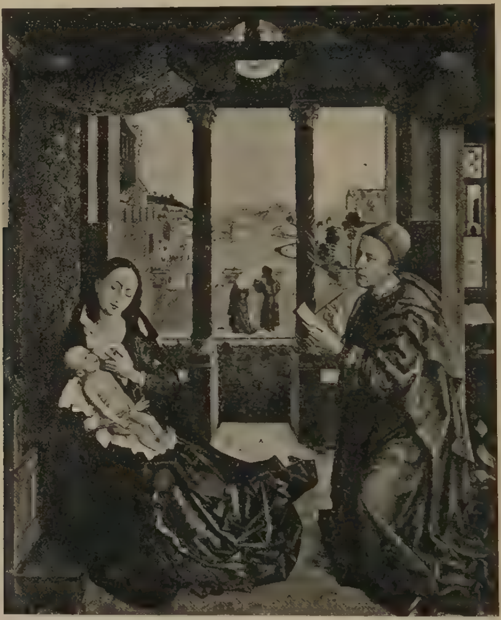

FIG. 3.—Rogier van der Weyden (1400–1464): St. Luke in physician's garb.

in time, actually read into the decrees issued by the Councils of the Church,* thus continuing the spirit of the edicts pronounced by the better sort of Roman emperors. In 314, the Council of Ancyra decreed that a woman who killed her offspring should not be permitted to enter a church for the rest of her life. The Council of Nicæa (325 A.D.) decreed that, in each Christian village, a xenodochion, or hostelry for the sick, poor and vagrant, should be established. Some of these xenodochia became brephotrophia or asylums for children. The Council of Vaison (442) provided that an abandoned child should find sanctuary in a church for ten days, that its parents might be found, after which false claims upon the child were punishable by the Church laws against homicide. This was confirmed by the Councils of Arles (452) and Agde (505), and mothers, who were driven to abandon their new-born offspring through shame or poverty, now left them in the marble receptacle at the church door. This privilege was freely granted at the Council of Rouen. The Council of Constantinople (588) compared the crime of infanticide to that of homicide, and finally Sixtus V (1585–1590) and Gregory XIV (1590–1591) decreed that those guilty of infanticide should suffer capital punishment. Finally, the legal code of Justinian (528–534) conferred absolute liberty upon foundlings, and a law of 553 decreed severe punishment for the enslavers of exposed infants. These drastic enactments, which indicate the frequency of infanticide in the early days of Christian Rome, were the direct outcome of the teachings of the Fathers of the Church. When we reflect that much of the antagonism of the proud Roman toward the early Christians is voiced in the famous sarcasm of Gibbon—that their religious scruples "contributed rather to exclude them from the service than to excuse them from the honors of the State and the Army," we can appreciate all the more the courage which impelled them to live up to their convictions in the stand they took for the rights of the child. As Payne says, when "Church and State unite in defense of the child's right to live, then, for the first time in history, religious and civil law became identical with humane sentiment." Among the Gaulish and German barbarians, the *patria potestas* was absolute. Exposure and infanticide were not infrequent, and were punishable in the Salic, Alemannic, and Visigothic codes by a *wergeld* (blood-money), which was only in the nature of a light fine. The Visigothic Code was more severe in the matter of abortion.

In the Dark Ages, thousands of children were exposed, abandoned or sold into slavery by the impoverished inhabitants of Gaul, Germany and Britain, and not only did those wanderers sell their own offspring and the exposed infants they had picked up, but even stole the children of the well-to-do for this traffic. Some of this misery was alleviated by holy men, who purchased these children outright as chattels of the Church.

In 787, **Datheus,** Archbishop of Milan, founded the first asylum for abandoned infants in the following declaration:

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* Terme and Monfalcon, *op. cit.*, pp. 78–81. Payne, *op. cit.*

"Now, therefore, I Datheus, for the welfare of my soul and the souls of my associates, do hereby establish in the house that I have bought next to the church, a hospital for foundling children. My wish is that as soon as a child is exposed at the door of a church, it will be received in the hospital and confided to the care of those who will be paid to look after them."*

The foundlings thus cared for were taught a trade and given their freedom at the age of eight.

FIG. 4.—Hans Holbein the Elder (1460–1524): Birth of the Virgin.

Other **foundling asylums** were later opened at Montpellier (1010), Marseilles (1199), Embeck (1274), Venice (1380) and Florence (1421). In the fifteenth century, there were 900 children in the foundling asylum at Naples. Others existed at Rome, Berglac and Troyes. A new asylum was opened at Milan in 1168, and in 1204, Innocent III, moved by the many bodies of infants fished up out of the Tiber, dedicated part of the hospital of Santa Maria in Sassia (1198) to the care of foundlings. The famous Spedale degl' Innocente at Florence was founded on October 25, 1168. Another was built by Brunelleschi in 1450. The first combined lying-in hospital and foundling asylum was founded by Enrad Fleinz at Nuremberg in 1331. In 1362, a similar orphan asylum was founded at Paris. A bull of Nicholas IV gives a long list of these institutions in Italy, Sicily, Germany, England, France and Spain.

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* Payne, *op. cit.*, p. 294.

In 1523, the Hôtel Dieu of Lyons, the oldest hospital in France, began to take in children. But the new movement for the protection of friendless children was to culminate in the devotion and labors of St. Vincent de Paul (1576–1660).

In the art of the Middle Ages, the Madonna and Bambino were favorite themes of painters, and many scenes in the lying-in room, including the bathing and swathing of the new-born, are preserved in oil, fresco, majolica, ivory relief and the wood-cuts of the time.

The lying-in room is usually represented as filled with busy people, and the nurse-maid is often figured as testing the temperature of the water for the baby's bath with bared feet. Breast-feeding was the rule everywhere, and the wet-nurse as foster-mother of the child, held her own until the 19th century when "the sucking-bottle, a kind of pocket wet-nurse, was her undoing" (Forsyth).* That the danger of suffocating infants by overlying was recognized is indicated in a German placard of 1291, cited by Sudhoff (Dresden Catalogue, item 6375), forbidding mothers from taking to bed with them infants under three years of age.

In medieval medicine, there was much excellent surgery, and the Jewish concept of the actuality of contagion was definitely read into the many hygienic ordinances improvised by municipalities against leprosy, bubonic plague and syphilis. Internal medicine was, however, mainly scholastic in character, and most treatises of the time were either translations or compilations from the medical writings of the ancients. This tendency of the pre-Renaissance period, receptive yet credulous, may be summed up in the words of Dr. Johnson.†

> "Learning was then rising in the world; but ages so long accustomed to darkness were too much dazzled with its light to see anything distinctly. The first race of scholars in the fifteenth century, and some time after, were for the most part, learning to speak rather than to think, and were therefore more studious of elegance than of truth. The contemporaries of Boethius thought it sufficient to know what the ancients had delivered. The examination of tenets and of facts was reserved for another generation."

In other words, the internists of the time frittered away their opportunities, for the most part, in the attempt to achieve huge summaries of everything known in the past (*summa medicinalis*), after the fashion of Galen, the Byzantine writers and Avicenna. Where internal medicine is really forward and flourishing, as in the eighteenth century, pediatrics is sure to thrive.

The Middle Ages made no contributions of value to the literature of pediatrics, unless we include the three treatises of Bagellardo, Metlinger and Roelants, which were published by authors who flourished long after the invention of printing.

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* D. Forsyth, Proc. Roy. Soc. Med., London, iv (1910–11), pt. 1, Sect. Dis. Child., p. 113.

† Samuel Johnson, "A Journey to the Western Islands of Scotland." London, (1775).

In the palmy days of the School of Salerno, the writers of the twelfth and thirteenth centuries began to produce lengthy treatises on the practice of medicine, in which the different local diseases were handled *seriatim* "from head to heel" (*a capite ad calcem*). Pediatric knowledge, in such treatises as these, was not segregated and individualized, but was scattered about through the chapters on epilepsy and other diseases liable to affect infancy. Thus the gynecological treatise of Trotula (*De passionibus mulierum*) contains, contrary to ancient custom, short chapters on the regimen of infancy, the election of a wet-nurse, and no more. This is also true of the *Physica* of St. Hildegarde (1099–1179). The obstetric portion of the Breviary of Arnold of Villanova (1235–1312) treats of a few female complaints with lengthy directions for the prevention of conception and the artificial production of pseudo-virginity (*ut mulier non concipiat, et ut virgo videatur*). The same thing (*De sophisticatione vulvæ*) is found in the Compendium medicinæ (1510) of Gilbertus Anglicus (Handerson). The 13th century *Régime du corps* of Aldebrandino of Sierra contains two short chapters on the hygiene of infancy, childhood and adolescence.* The later writers on internal medicine, were, by preference, translators, "aggregators" (compilers), "concorders" (arrangers) and "conciliators" (reconcilers of disparate doctrine). In the huge treatises of Gilbertus Angelicus (–1250), Taddeo Alderotti (1223–1303), Peter of Abano 1250–1315), Bernard de Gordon (*circa* 1285–1307), and Niccolò Falcucci (–1412), pediatrics is not anywhere featured as a separate subject, as in Soranus, Oribasius and Paul. The *Practica* of Savonarola (1390–1462) again treats only of diseases "from top to toe" (*a capite ad pedes*), after the Salernitan fashion. The tendency of internal medicine was purely scholastic. The outstanding contribution of the Middle Ages to infant welfare is to be found, not in the books, but in the efforts of the Church to check abortion and infanticide.

THE RENAISSANCE PERIOD

(1453–1600)

The Revival of Learning in Europe really began with the printing of the Gutenberg Bible at Mainz (1454), one year after the fall of the Eastern Roman Empire (1453). After that event, the Greek scholars of Byzantium began to pour into Italy, and after the sack of Mainz (1462), the German printers spread over Europe, and began to publish books everywhere. The effect of all this was to disseminate knowledge in a rapid, effective manner, and with the revival of Greek culture there arose a new species of physicians, the medical philologists who supplanted the medieval compilers and commentators, and introduced the critical, challenging spirit in their examination of the older medical writings. In Germany, France and England, many medical books and tracts were published for the first time in the vernacular, and, through this medium, botany, surgery, obstetrics, ophthalmology took on a new lease of life. Anatomy received a tremendous impetus at the hands of Leonardo da Vinci, Vesalius, Eustachius and Fallopius, pathology was forwarded by Benivieni, the modern theory of contagion was stated in striking form by Frascastorius, chemical therapeutics was grounded by Paracelsus, and gynecology, pediatrics, medical jurisprudence and veterinary medicine began to be individualized in books devoted to these specialties alone.

Infantile mortality in the sixteenth and seventeenth centuries was very high, owing to the low estate into which public and personal hygiene had fallen, on account of the many wars and epidemics with which Europe had been plagued, and the indifference of the aristocracy to the misery of the people. By decrees of the Parliament of Paris in 1547 and later, the great nobles were required to care for the foundlings abandoned in their domains, but the mandates were evaded or neglected. Although the churches and monasteries still looked after infants left at their doors, children were frequently found dead from cold and hunger on the streets, or were fished up drowned out of the sewers. Froude, at the beginning of his History of England, speaks of the almost stationary condition of the English population at this time. Yet the artists of the German and Italian Renaissance glorified maternity as the chief end of womanhood, and the lying-in room was frequently represented by Holbein and others, showing the modes of bathing, swaddling and cradling the infant, the nurse usually testing the temperature of the water with her bared foot.

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* Le Régime du Corps de Maître Aldebrandin de Sienne, texte française du xiiie siècleéd. L. Landouzy et R. Pepin, Paris (1911), pp. 74–80.

Of the many pediatric treatises and tracts of the Renaissance period, the earliest were the late fifteenth century incunabula of Bagellardo, Metlinger and Roelants, the latter of which was destined to be almost obliterated under the name of Sebastianus Austrius.

Pietro **Bagellardo,** of Fiume (Bagellardus de Flumine) (–1494) began to teach philosophy at the High School in Padua in 1441, and medicine about 1444–58. In 1472, he became professor ordinarius of theoretical medicine, and continued to teach at Padua for eight years. He was known and respected even at Venice, whither he was invited by the Doge to view the remains of St. Luke in the church of St. Justina. He settled in Venice in 1480, and died there in 1494.* In 1472, he published the first distinct treatise on pediatrics (*De aegritudinibus infantium*) one of the first medical incunabula to be printed. Three separate editions of this work exist, *viz.*, the small quarto of 40 leaves (80 pages) published at Padua on April 21, 1472 (Hain, 2244), an Italian edition (*sine loco*) published on March 10, 1486 (Reichling, 414) and the Paduan edition published on November 10, 1487 (Hain, 2245).† The editions of 1472 and 1488 can be seen in the Surgeon General's Library.

This treatise, which follows that of Rhazes very closely in arrangement of contents and subject matter, begins with a florid dedication to Niccolò Truno, Duke of Venice, passing, over the page, into Part I, which deals with the care of the infant in the first month of life. After the usual obstetric directions as to the careful examination of the newborn before severing the umbilical cord, the nurse is directed to place the child in a pleasantly warm bath, neither too hot, nor too frigid, and not salted after the Greek fashion; the child's head being supported by the left hand of the nurse and the right hand cleansing all parts of the body with gentle friction; the child is then carefully wiped, swathed and cradled in a cool shady part of the house; its first food should be sugared baked apple (*pomi cocti perfecta coctione permixto zucaro*). Minute directions for lactation, choice of wet-nurse and care of the child up to the end of the first month follow. The directions for crooning a song while rocking the cradle read very quaintly. Part II consists of 22 chapters dealing with infantile diseases, *viz.*, *saphatie* (tinea capitis) and favus, epilepsy, colic (*spasmus*), wakefulness, eye diseases (ophthalmia, tumefaction, strabismus), ear diseases (hemorrhage, otorrhea), abscess of the ear, aphthæ (*alcola*), gingivitis, fissure of the lips, abscess of the throat, cough and rheumatism, diarrhea (*fluxus*), constipation (*stipticitas*), tenesmus, worms, tympanites (*tumor ventris*), dysuria, incontinence of urine, umbilical, inguinal and scrotal hernia (*ramex*) and pruritus, pustules or excoriations (intertrigo) on the legs, thighs, back and body.

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* K. Sudhoff, Janus, Amsterdam, xiv (1909), pp. 468–469.

† The bracketed figures refer to the check numbers of these incunabula in the catalogues of Hain and Reichling.

Bartholomæus **Metlinger,** a son of Peter Metlinger, an Augsburg physician, is mentioned in the tax-lists of Augsburg for 1472, and, in the same year, was enrolled for instruction at the new University of Ingolstadt. He died circa 1491–2, leaving a widow and children.* On December 7, 1473, his "*Regiment der jungen Kinder,*" a folio incunable of 27 leaves (Hain, 1112) was published at Augsburg by Günther Zainer. This, the earliest pediatric treatise in the vernacular, passed through 8 editions (1474, 1476, 1497, 1500, 1511, 1531, 1539) and was turned into modern German by Ludwig Unger in 1904.† The 1497 edition has an illustrated title-page, representing a German domestic interior, with a swaddled child in the cradle, rocked by its mother's foot. This work, in essence a popular treatise, is, as Abt says, of doubtful scientific value.

Metlinger draws liberally upon the Greek and Arabian writers. Chapter I deals with infant hygiene up to walking and talking, after the practical fashion of Soranus. Chapter II deals with infant nutrition. It contains the first mention of the nippled nursing can ("*tütlein oder krieglein*") and the artificial teat (*zepflin*) for pap. Chapter III with eruptions of the scalp and face (*nerys*), for which a mercurial salve is recommended, hydrocephalus (*Wechselbalg*), meningitis (*durstig*), wakefulness (*Wachen*), convulsions (*Vergicht*), paralysis, otorrhea, conjunctivitis, strabismus, teething, tumors of the neck, aphthæ, bronchial catarrh, disorders of digestion, jaundice, diarrhea (*rur*), constipation, prolapse of the rectum, worms and pains in the body, umbilical and scrotal hernia, urinary calculus, cutaneous ulcers, fever, erysipelas (*gesegnet oder ungenad*), measles and smallpox (*durchschlechten und platern*). The therapy is extensive, often based on personal experience ("*und ich hab es bewärt*"). Chapter IV deals with teaching the child how to run, and its training up to the sixth year, when it should begin studies. Wine should not be given to children under 7, preferably not to boys before 12, nor to girls before 14.

The pathology is throughout humoral (Sudhoff).‡

Cornelius **Roelants** (1450–1458), of Mechlin (Brabant), matriculated (1466) at the University of Louvain, where he graduated in medicine in February, 1480, and was hospital- and city-physician at Mechlin during 1498–1525. He became a highly esteemed practitioner among the nobility, even attending the daughter of Emperor Maximilian. On February 10, 1494, he married Cæcilia von Duffel, who died on February 16, 1519, leaving a son and a daughter. Roelants himself died, at the age of 75, on September 1, 1525 (Sudhoff). About 1483–4, he published a pediatric treatise of 117 leaves (numbered 78–194) of which only the first 77 are printed. The book is dedicated to Philip I (the Fair), Duke of Burgundy. Of this incunable, exhumed by Sudhoff, only two perfect copies are known, *viz.*, those in the Hunterian Museum at Glasgow and the University Library at Leipzig, but there are a few loose leaves in the University Library at Cambridge. Although this text is not accessible, a good account of it is given by its discoverer, Sudhoff.*

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* Huber, München. med. Wochenschr., lv (1908), p. 1499.

† L. Unger, "Das Kinderbuch des Bartholomäus Metlinger." Leipzig (1904).

‡ K. Sudhoff, "Deutsche Medizinische Inkunabeln." Leipzig (1908), pp. 38–43. For a good analysis of the contents of Metlinger, see R. Landry, Wien. med. Presse, xliv (1904), pp. 1382–1390.

After the fashion of the pre-Renaissance compilers who sought to arrange *seriatim* all the opinions of earlier writers on a given subject, Roelants styles himself "aggregator Cornelius" and "aggregator Mechlinensis," patting his authorities on the back with a personal "*bene dicit.*" He draws on all known sources, from Hippocrates and Rhazes, Gerard of Cremona and Gilbertus Angelicus, to Saliceto and Argillata. Sudhoff has further traced his sources to an anonymous pediatric MS. of the 13th century which he has exhumed in no less than 17 medieval codices in the Vatican, Oxford and elsewhere, and to a pseudo-Galenic "*practica puerorum*" of late antiquity, in two MS. codices at Florence (14th century) and Prague (15th century). Although Roelants compiles opinions as a professional "aggregator," he does not withhold his own experience. He speaks of the advantages of blood-letting in the nurse instead of the infant; recommends the blue ring-dove above other doves as an article of infantile diet; shows how the lentil of the Low Countries may be substituted for the "ligni cornua;" describes cancrum oris, feeble locomotion, tumors and treatment of ear diseases from his own experience; and criticizes textual corruptions in the MS. of Avicenna.

Fifteen years after the death of Roelants, as Sudhoff has shown,† the credit of his work was practically taken away from him by Sebastian Ostricher (**Sebastianus Austrius**) (–1550), of Ruffach (Alsace), a learned philological physician who practised at Colmar and published a commentary on the section on personal hygiene in Paul of Ægina (1538). Exasperated by the "barbarous kitchen-Latin" of Roelants, Ostricher undertook to make the text more readable and, in 1540, issued it, rearranged, emendated and dressed up for posterity, as a new work, under his own name. Although he acknowledges the Flemish physician's work as the basis of his own in the preface, he ignores him on the title-page, and the book of Roelants, in this form, is now known to pediatrists as "Sebastianus Austrius." This book was reissued at Leyden in 1544, and again, with a commentary by Nicolaus Fontanus, at Amsterdam in 1642. As a summarizer of then existing knowledge, Sebastianus Austrius, the supplanter of Roelants, is credited with the outstanding pediatric text of the sixteenth century.

Omitting infant hygiene and nutrition, the author plunges into his subject with descriptions of 54 diseases arranged "*á capite ad calcem*" (from siriasis to femoral intertrigo), in as many chapters. The treatment is scholastic and the work should be of great value to pediatrists who wish to trace the changes of doctrine in the texts of classical antiquity and the Middle Ages. The titles of diseases heading the successive chapters include all the synonyms, as in the Systems of Allbutt and Osler. The *saphatie* of Avicenna is identified with tinea capitis, favus (Rhazes) is "kerion;" night-fears are "*pavores*" (Hippocrates, Galen);

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* Sudhoff, Janus, Amst., xiv (1909), p. 465; xx (1915), p. 443.

† Sudhoff, Janus, Amst., xiv (1904), pp. 481–484.

epilepsy is the *morbus comitialis* of the Greeks, the *mater puerorum* of the Romans, and the *morbus regius* of the vulgar; paralysis is "*resolutio nervorum;*" infantile convulsions may range from colic to tetany; *glaucedo* (γλαύκοματα) or hypochymata is not the glaucoma of Graefe, but a greenish suffusion of the eyes; ptilosis and psorophthalmia are featured; the *parulides* of Paul are abscesses of the gums and jaws; epulis is the *vesica* of Rhazes; aphthæ is synonymous with *alcola* (Avicenna), *calaba* (Paul) and *ulcus oris* (Pliny); quinsy is *squinantia;* a weak stomach is *stomachus fractus* (Avicenna); diarrhea is *alvi fluor,* constipation *alvus sicca;* the chapter on incontinence of urine is entitled "*de meientibus*" (Paul). The work is prefaced by a dedication to Ferdinand, King of Bohemia, and the Hippocratic aphorisms on infantile diseases. It concludes with 19 aphorisms on infant hygiene and nutrition, of which the following are samples:

3. The infant is to be fed solely on milk up to dentition.

4. Wine and beer are harmful to children as befogging the brain and perturbing the mind by heat.

17. Three modes of lightening the pangs of infancy: apposition of the nurse's breast, gentle dandling and pleasant modulation of the voice.

18. Red coral suspended to the suckling's neck, reaching from the mouth to the stomach, prevents the vomiting of milk and promotes its digestion.

A work of the same scholastic stamp is the large quarto treatise (*De morbis puerorum tractatus*) of Geronimo **Mercuriali** (1530–1606), of Forli, published at Venice in 1583. Mercuriali was a learned medical graduate of Padua, who acquired his extensive knowledge of ancient medicine by seven years of study at Rome, at the instance of Cardinal Farnese. He held the chairs of medicine at Padua (1569–87), Bologna (1587–99) and Pisa (1599–1606). In 1569, he published a learned illustrated treatise on the gymnastics of the ancients, which passed through five editions and made his reputation along with the first formal treatise on skin diseases (1572), a treatise on gynecology (1582) a bilingual (Greek and Latin) edition of Hippocrates (1578) and many learned commentaries on Hippocrates and on difficult passages in the ancient writers (1571). His medical treatises were spoiled by the fact that he allowed his pupils to prepare them for the press. In consequence, the style is diffuse and verbose.

The pediatric treatise, described by Hennig as "an inconsiderable book which long passed as authoritative," was reprinted twice, the second edition (1584) containing Mercuriali's translation of Alexander Trallianus on worms. As with Roelants and Austrius, the text of Mercuriali is that of a medieval "aggregator." The work is divided into three books, the third being devoted entirely to intestinal worms. The arrangement of chapters is irregular; the longest are those on measles and smallpox, emaciation (*de macie*), epilepsy, and stammering. Among the new titles included are scrotal hernia (*ramex*), intertrigo, pernio, putrid fever (*febris synochus*), disordered speech, mutism, disorders of sensation (*de vitiis sensus communis*), dyspnea and scrofula. On the whole, as Hennig intimates, a much-overrated book.

Perhaps the earliest pediatric treatise in the vernacular is "*The Boke of Children*" of Thomas **Phayre** (or Faier) (1510?–60), a charming black-letter appended to "The Regiment of Life" (London, 1545), a popular version of the Salernitan "Regimen sanitatis" by the same author. Phayre was a learned lawyer, physician and translator, an Oxford M. D. of 1558, who later Englished the first seven books of the Æneid.

He begins his little pediatric tract, with a frank avowal of his disinclination to deal with the generation and hygiene of the infant as "pertaining only to the office of a midwife," yet none the less he goes into infant nutrition through 8 pages, urging that the mother nurse her own child. He then gives brief descriptions of 40 diseases, the "remedye" being paragraphed in each case. Among these are "aposteme of the brayne," "swelling of the head," "watching out of measure" (wakefulness), "terrible dreams," "the fallyng evill" (epilepsy), "crampe," "styfnesse of lymmes," "bloodshoten eyes," "nesying out of measure" (coryza), "Quynsye," "straytnesse of wynde" (dyspnea), "colyke and rumblyng in the guttes," "brustynge" (scrotal hernia), "fallyng of the fundament," ague, "kybbes" (pernio), and "swellyng of the coddes," which may be the orchitis of mumps (Hippocrates). The descriptions of diseases have a quaint practical flavor; the treatment is mainly herbal, and sometimes suggests the "frightfulness" of the first London Pharmacopœia (1618).

A far more original pediatric treatise than any of those mentioned is that appended to the 1612 edition of the *Practica der Wundartzney* (1598) of the Swiss surgeon Felix **Würtz** (1518–1575), which in the English translation of 1656, appears as *The Children's Book.* This "*Children's Book*," the work of a natural-born, self-taught surgeon, is delightfully fresh and vigorous, does not lean upon the old authors, actually tells us something new, and is, even today, a living demonstration of the fact, that the surgeon of Renaissance, dealing daily with the data of actual experience, was capable of better and more practical bedside thinking than the clinical scholiast of the period. "I presume not to write of things which I never had an experience of," says Würtz —"those I leave unto wiser men." This little book is also the first treatise on **infantile surgery.**

After some sensible directions as to the choice of a wet-nurse, Würtz vigorously scores the practice of tight swaddling; gives timely cautions as to the posture of the child in the cradle, the need for gentle rocking; attention to the cause of crying; cramp from lying in wet or cold places, bathing and prompt wiping, especially of the head. Scrubbing the interior of the mouth is particularly bad in thrush, and blisters of the cheeks, tongue or throat. The Swiss methods of spoon-feeding, to prevent burning with hot pap are described, with the danger of injuring the child's mouth by the spoon, and the drinking bottle is to be watched as a source of putrefaction. Itching, burning blisters, "fellow feeders" (comedones), smarting pains, running eyes, sore eyes are paragraphed. Würtz gives his own personal experience as to the harmful effects upon the eyes of bright light and shining things generally. Conrad Gesner himself prescribed venesection in his case. "Winding children into clouts" is again denounced, and a long orthopedic section "of crooked and lame children" follows· "a fit garment for children to wear in their cradles," the danger of rough dandling, carrying and dancing on the knee, fractures, dislocations, convulsions and blindness from these causes, the dangers of too early standing and walking by means of stocks and running stools, and the necessity of protecting the child's face from flies, make up the rest of this straightforward exhortation. The surgeon's quaint piety, his big humanity, and his vigorous vernacular suggests the sermons of Bishop Latimer (1562) and Abraham á Sancta Clara. As the first contribution to infantile orthopedics, this little work is easily the most original pediatric treatise of the sixteenth century.

Other pediatric treatises were published by Michel Angelo Blondi (Venice, 1537), Petrus Jacobus Toletus (Leyden, 1538), Paul Cornelius (Basel, 1540), Hieronymous Montanus (Lyons, 1550), Ludovico Lobera de Avila (Pincia, 1551), Marco Mironi (Turin, 1553), Leonelli (Venice, 1557), Johan Kueffner (Venice, 1557), B. Russeus (Louvain, 1559), L. Faventinus de Victoriis (Leyden, 1574), Omnibonus Ferrarius (Brescia, 1577), and Jacob Tronconi (Florence, 1594). A

French medical poem on breast feeding (*Manière de nourrir les enfans à la mamelle*) was published by Scaevola Gaucher de St. Marthe in 1598, and translated into English as "Paedatrophia" by H. W. Tytler (London, 1797). Tracts and dissertations on monsters by Sorbinus (1570), Limmer (1594), Euonymus (1595) and Winrich (1595); a poem on infantile atrophy by Julius Alexandrini (Zürich, 1559), a dissertation (*De tabe infantum*) by Reusner (Basel, 1582); a colloquy on dentition by F. M. de Castrillo (Valladolid, 1557); dissertations on worms by H. Brille (1540), H. Gabucinus (1549), Savanarola (1560), Nymann (1594), Hoffmann (1595), and a dissertation on rachitic infantile atrophy by Teichmeyer (Jena, (1515) are listed in Meissner's bibliography of pediatrics.

The epidemics of smallpox and measles in Germany (1493), Sweden (1578), and elsewhere occasioned a large number of tracts on smallpox and measles which were a sort of prelude to the vast smallpox literature of the seventeenth and eighteenth centuries. **Syphilis,** first mentioned in the Edict against Blasphemers of Maximilian I (1495) and named in the poem of Frascastorius (1530), was the subject of a large number of treatises by Konrad Schelling (1496), Joseph Grünpeck (1496), Leonicenus (1497), Joh. Widmann (1497), Montagnana (1498), Torella (1500), Lacumarcino (1524 *vel subseq.*), Massa (1532), Fernelius (1538), Fallopius (1564) and Luisinus (1566). Among the original descriptions of new diseases were those of **typhus fever** by Fracastorius (1546), **varicella** by Ingrassias (1553) **tabardillo** or Mexican typhus by Francesco Bravo (1570), and **chlorosis** (*morbus virgineus* by Johann Lange (1554). **Whooping cough** (*quinta*) was described for the first time in 1578 by Guillaume de **Baillou** or Ballonius (1538–1616), a dean of the Paris faculty, whose posthumous writings include treatises on convulsions (1640), rheumatism and dorsal pleuritis (1642), diseases of virgins and matrons (1643), and a disputation of 1595, in which it is maintained, in consonance with the old Hippocratic teaching, that those who acquire a gibbous spine, from cough or asthma, before puberty, will soon die. Baillou's account of whooping cough was followed by the "*Synopsis novi morbi*" of Beckel (Helmstädt, 1580), in which the ravages of the disease (*catarrhus febrilis*) through the length and breadth of Europe are described.

The facies of **adenoid vegetations** is reproduced for the first time, *sans le savoir*, in Lucas van Leyden's portrait of Ferdinand I of Spain (1524), and the many paintings of the prognathous Hapsburgs and Medici would now be regarded by dentists as figurations of malocclusion.

In the late fifteenth and sixteenth centuries, all modes of **artificial nutrition of infants** were in vogue. In default of the mother's breast or the wet-nurse, the child was fed on cow's milk or goat's milk by means of sucking horns, sucking cans with artificial nipples, the spoon, or by sugar lumps and bread rubbed into a piece of linen, shaped into an artificial nipple.

The sucking horn (*cornette*) is mentioned, in *Robert le Diable*, a French metrical romance of the 13th century, in *Die gute Frau*, a German poem of the same period, and in the Autobiography of Thomas and Felix Platter (16th century), in which Thomas describes himself as weaned by means of a horn, his mother not being able to nurse him on account of inflammation of the breast. The sucking can mentioned by Mettlinger as *tüttlin* (1473) and called *memlin* by Albertus Magnus, was provided with a nipple or a spout, and of varied shape, sometimes simulating the contour of the breast, sometimes as crude in form as the pottery of primitive man, sometimes resembling a barrel, an hour-glass, or a bell. Spoonfeeding and sucking cans are shown in three 16th century pictures in the Cologne museum, The Three Kings (H. Bles), The Adoration of the Shepherds (M. van Heemskirck), and a triptych of the Virgin by an unknown Frankfort painter. The artificial teat (*Zulp or Zepflin*) mentioned in Mettlinger (1473) and in Röslin's *Rosegarten*

(1513) is figured in Albrecht Dürer's "Madonna with the Greenfinch" of 1506 (Kaiser-Friedrich's Museum, Berlin), and in a modern Domestic Scene by J. G. Hantsch (Leipzig Museum). Breast-feeding, spoon-feeding, and can-feeding are all shown on a woodwork altar from St. Gertrude's Church at Lübeck (late 15th century, now in the Lübeck Museum—Brüning).*

In the Renaissance period, much attention was paid by the writers of the time—Erasmus, Rabelais, Ascham—to the education and training of children. Rabelais, in particular, ridiculed the time-honored custom of stuffing a lad with dull book-earning, and advocated education in the old Greek and the modern sense, as a deliberate drawing out of the latent faculties by the aid of open-air exercise, equitation, swimming, archery, dancing, etc. In England, among the wealthy and the well-to-do, this cult took the peculiar line of sending the children away early to live in the homes of great nobles as pages and henchmen, in order to learn the rules of etiquette, music, the theory of precedence, how to carve and other essentials of the training of gentlemen and gentlewomen. These retainers were sometimes austerely handled by the great, and among children sent to school or indentured to apprenticeship in the trades and crafts, punishments were severe and drastic. Longchamps, Bishop of Ely, is said to have pricked the sons of nobles who acted as his servants, with a goad, "mindful of his grandfather of pious memory, who, being of servile condition in the district of Beauvais, had, for his occupation, to guide the plough and whip up the oxen." Relics of this austere preoccupation with etiquette and good form are to be found in such treatises as John Russell's Book of Nurture, Wynkyn de Worde's Book of Kervynge (1513), The Book of Curtasye (Sloane Ms., 1460), The Babees Boke, Lerne or be Lewde, The Lytyll Children's Lytel Boke, Stans Puer ad Mensam, the Birched School-

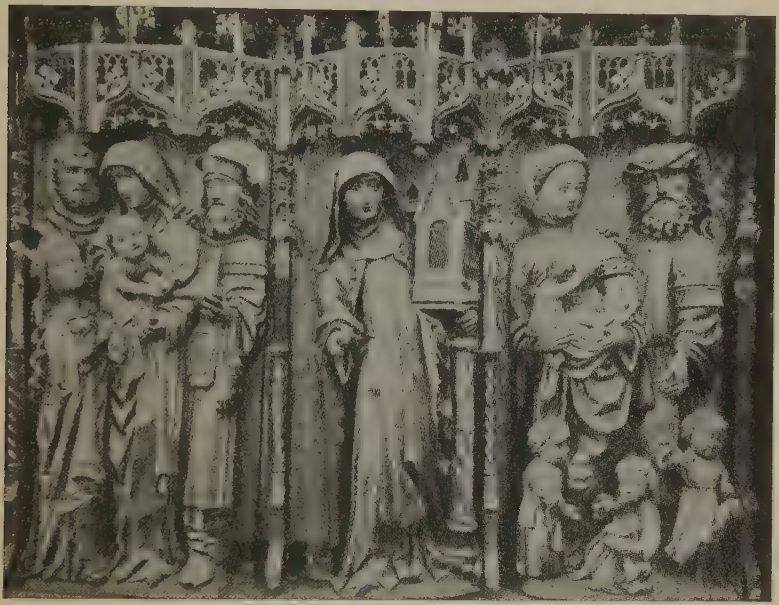

FIG. 5.—St. Gertrude's altar (15th century, showing breast-feeding, spoon-feeding and bottle-feeding (Lübeck Museum). (From H. Brüning: Geschichte der Methodik der Künstlichen Säuglingsernahrung, Stuttgart, 1908, p. 77.)

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* For other pictures, see Auvard and Pingat, "*Hygiène infantile et moderne.*" Paris (1889), pp. 59–74; and H. Brüning, "*Geschichte der Methodik der künstlichen Säuglingsernährung.*" Stuttgart (1908), *passim.*

Boy (1500), etc., all which have been preserved in F. J. Furnivall's Early English Meals and Manners (Early English Text Society, No. 32, London, 1868).

THE SEVENTEENTH CENTURY

The seventeenth century was an age of great poets (Shakespeare, Milton), great dramatists (Calderon, Molière, the Elizabethans) great philosophers (Spinoza, Bacon, Locke, Descartes), great painters (Velasquez, Rembrandt), great musicians (Bach, Purcell) and great mathematicians (Newton, Halley, Leibnitz). In this age, the English physician William Gilbert wrote his epoch making treatise on magnetism (1600), Harvey demonstrated the circulation of the blood (1616–28), the anatomical discoveries following Vesalius and Harvey were all of physiological import, microscopy was founded by Kircher, Hooke, Leeuwenhoek, and Swammerdam, histology by Malphighi, physiological optics by Kepler, Descartes, Mariotte, and Scheiner, the physiology of digestion by Peyer, Brunner, and de Graaf, the physiology of respiration by Boyle, Hooke, Lower, and Mayow, vital statistics by Graunt, Petty, and Halley. Transfusion, anatomic injection, the obstetric forceps, timing the pulse, and clinical thermometry were introduced, and internal medicine was represented by the great name of Thomas Sydenham.

In the art of the seventeenth century, children play a prominent part, whether in the wonderful "Las Meniñas" of Velasquez, Van Dyck's "Baby Stuart," Rubens' many pictures of the charming Helena Fourment and her children, Rembrandt's "Venus and Amor" (Hendrickje Stoffels) and his comical "Ganymede," or Johan van Neck's painting of a dissection conducted by Dr. Frederik Ruysch (1683), in which a child plays with an infantile skeleton in the corner.

Infantile pathology is represented in the cretinoid or hydrocephalic dwarfs of Velasquez, Ribera's portrayal of a paralytic boy, Gabriel Metsu's Feverish Child, and the picture of a girl afflicted with dystrophia adiposo-genitalis by Juan Careño de Miranda. Rubens delighted in the representation of healthy, round-limbed, laughing babies. His "Garland of Fruits" symbolizes, in a manner, the eugenic ideal of the late Renaissance, for the artists of the period glorified the state of maternity in the full-bodied woman, fit to be "the justified mother of men."

Yet the seventeenth century was an age otherwise notable for cruelty to children.

In an *arrêt* of the Parliament of Paris (September 3, 1667); it was decreed, in the interests of the special hospitals, that the *grands seigneurs* or high officers of justice should be held financially responsible for the care of all infants of unknown parentage found on their lands and taken to the hospitals; but the tight-fisted nobles did not live up to their obligations, and the poor foundlings were shifted from place to place by those who did not want them. In Paris, as in ancient Rome, unfortunate mothers threw their offspring into the sewers, abandoned them at the doors of hospitals, or left them in the streets to die. The laws were severe—hanging for infanticide, whipping and disgrace for abandonment, declaration of paternity in seduction—and rigidly enforced, but the full penalty was paid by the infants themselves.

FIG. 6.—Rubens: The Garland of Fruit (Düsseldorf Gallery). (Eugenic ideal of the late Renaissance Period).

Some children in the crowded charitable retreats were exposed anew or drugged to death with opium in order to keep them quiet; others were used as beggars, to make money, and some were artificially malformed to this end.* The extraordinary number of beggars, professional cripples, blind and deformed persons held up to ridicule in the etchings of Callot and the paintings of the elder Brueghel suggests that the thematic material of Victor Hugo's "*L'homme qui rit*" is not entirely exaggerated. In this novel, which deals with the surgical malformation of a child's face for political reasons, there is a chapter devoted to the professional buyers and sellers of friendless children (*los comprachicos*),† a strange affiliation of seventeenth century criminals who, as in the later Roman Empire, purposely lamed and maimed unfortunate children by a reversed orthopedic procedure (*chirurgie au rebours*). According to the romancer, the master of this art of facial disfigurement was a certain Dr. Conquest, who wrote a (perhaps mythical) Latin treatise on the subject. A Latin citation of the procedure is given from an alleged chapter "De Denasatis," as thus: "*Bucca fissa usque ad aures, genzivis denudatis, nasoque murdridato, masca eris, et ridebis semper*"‡—the ideal of the "false-face" mask from time immemorial.§ In some parts of Spain (Oyarzun, Urbistondo, Lesa,

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* Payne, *op. cit.*, pp. 302–305.

† Victor Hugo, "L'homme qui rit." Paris (1869), Chap. II.

‡ *Ibid.*, Bk. III, Chap. VI.

§ The artificial production of monsters is the theme of "The Artificial Changeling" of John Bulwer (1650–), and is mentioned by Fortunatus Licetus (1577–1657). See J. S. Billings, "History of Surgery." New York (1895), p. 46.

Astigarraga), says Hugo, nineteenth century mothers still intimidated their children with the threat that they would call the *comprachicos* ("*Aguardate, niño, que voy á llamar al comprachicos*"). Victor Hugo was described by Sainte Beuve as "the Frank energetic and subtle, who has mastered to perfection the technical and rhetorical resources of the Latin literature of the decadence." Hugo's citations from Conquest may have been mere literary *supercherie*, but his narrative is undoubtedly true to the spirit, if not to the letter of the times, as attested by the endeavors of **St. Vincent de Paul** (1576–1660). This devout man, who had once been captured by pirates off Marseilles and sold into slavery himself, was the noblest champion of the rights of friendless children between Datheus and such men as Lord Ashley, Oastler and Théophile Roussel. In the time of St. Vincent de Paul, an unknown woman of Paris began to collect in her home exposed infants

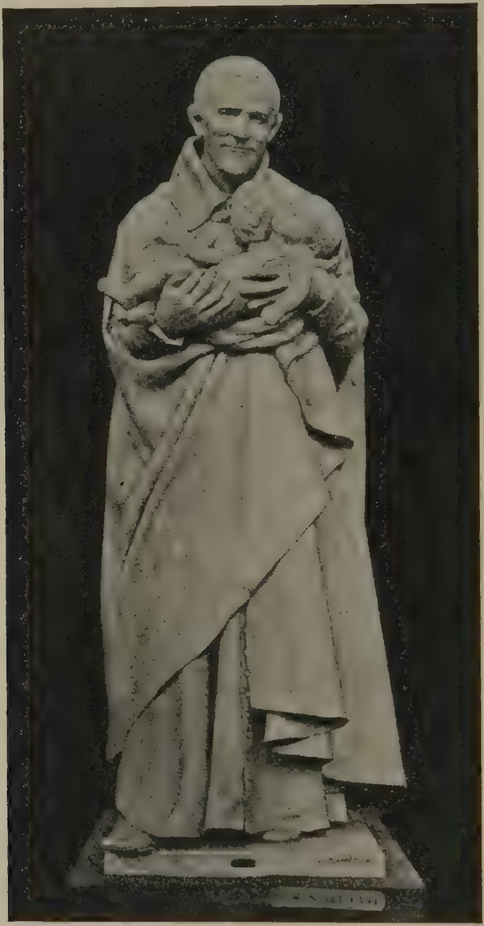

Fig. 7.—St. Vincent de Paul. (1576–1660). From a statue in the Panthéon, Paris, by Alexandre Falguière.)

brought in by gendarmes at night. This eventually proved too large a charitable contract for one person. Many infants died from lack of food, or were exposed again or turned over to charitable persons or institutions. The two servants in the establishment drugged the unfortunates to keep them quiet, and eventually took to selling them to pedlars and mountebanks (*bâteleurs*), who in turn used them for money making purposes. Returning from one of his missions, St. Vincent de Paul actually caught one of the mountebanks or *comprachicos*, of whom Hugo speaks, in the act of deforming the limbs of a child under the walls of Paris. "Barbarian," he cried, "how you deceive me—from the distance I took you for a man!" And snatching the child, he rushed across the city to denounce the infamy. He interested a number of great ladies in his cause, so that a small asylum was established, which was frequently changed for larger accommodations; and slumming parties were organized to gather in exposed waifs. Eventually Louis XIII donated 4000 francs per annum to the charity, and Anne of Austria 8000 francs after his death (1641). In June, 1670, the Foundling's Hospital (Hospice des enfans trouvés) of Paris was chartered and endowed with 12,000 francs by Louis XIV, although its actual annual expenses at that time were 40,000 francs. This led to the systematic conveyance of foundlings to Paris, for the narrow provincial towns would have none of them. Of 2000 infants transported from the provinces in this way, about 75 per cent. died in three months. A new law was accordingly passed imposing a fine of 1000 livres upon any wagoner who brought in an infant for purposes of exposure; and it was decreed that abandoned infants must be taken to the nearest hospital and, if necessary, cared for out of the public funds. To this day, Vincent de Paul is the patron saint of orphans and orphan asylums.*

In seventeenth century England, the rate of **infantile mortality** was also high.

In the time of the Stuarts, London became overcrowded, in spite of the depletion of the population by plague, sweating sickness, and smallpox. The rulers, from Elizabeth to Cromwell, opposed the building of new houses, and the surplus population swarmed to the waterside. "Four-fifths of the population of London," says Forsyth, "were crowded into the alleys and courts of out-parishes such as Wapping, St. Olave's, Lambeth, Whitechapel, and Spitalfields."† In consequence, sometimes half the children born in Restoration England died of disease. Two-fifths of the total deaths were those of infants under two years. In the hot summers of 1669–71, diarrhea killed 2000 babies in eight or ten weeks. Private letters of the period show that the well-to-do were little better off. Traill, im "Social England" speaks of the callous feeling of English parents for children in the Tudor period. Lady Jane Grey told Asham that her child-life was such that she thought herself "in hell."‡ In Stuart England, boy and girl marriages were encouraged.§ The main idea was to get rid of children, by apprenticeship among the poor, by early marriages or a round of visits among the rich. Suffocation of the child by overlying was sometimes resorted to by the unscrupulous. In Congreve's "Love for Love" (act I, sc. 1), produced in 1695, a spendthrift libertine says of the mother of his illegitimate offspring: "She knows my condition well enough, and might have overlaid the child a fortnight ago, if she had had any forecast in her." At birth, the newborn infant was salted (according to Galenic custom), tightly swaddled, dandled for a few minutes each day, kept upright by standing it up to its armpits in a go-cart and taught to walk by means of leading strings. The manual methods of dry-nursing were little known in Stuart England. Maternal and mercenary wet-nursing were the rule. In the English Bills of Mortality, children under two years (the period of teething) are grouped apart. John Pechey (1697) lowers the statutory period of weaning to 1½–2 years after birth, *i.e.*, not before the child had acquired all its teeth. For astrological reasons, a child could not be weaned at the wane of the moon, but preferably when the spring or autumn moon were full. Pap and chicken broth were the earliest artificial foods. To get the child accustomed to these, the mother's nipples were smeared with wormwood or aloes (Pechey). When meat diet was begun, Pechey recommended that it be "first chewed by the nurse."*

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* Payne, *op. cit.*, pp. 306–311.

† D. Forsyth, Proc. Roy. Soc. Med., London, iv (1910–11), pt. 1, Sect. Dis. Child., p. 117.

‡ Traill, Social England.

§ *Ibid.*

On the continent, dry nursing and hand feeding were well-known. The child was fed from pitchers, bowls, and glasses of varied shape, such as that seen in Adriaen Brouwer's "Baby drinking from a Glass" (Leipzig Museum) or the "Family of Fauns" of Jordaens (Nuremberg).

The Seventeenth Century was an age of individualism in thought and research and was more remarkable for monographs on special subjects than for exhaustive treatises. It was the age of the *Arbeit* rather than of the text-book.

Among the twenty pediatric treatises or tracts listed by Meissner are those of Mario Zucarri (Naples, 1604), Joh. Ceckius (Wittenburg, 1604), Jacques Guillemeau (Paris, 1609),† Johan Hucher (Cologne, 1610), F. P. Cascalis (Madrid, 1611), Amthor (*Nasocomium infantile et puerile*, Schleussing, 1638), James Primrose (Rotterdam, 1658), Walter Harris (London, 1689), Philip Grüling (Nordhausen, 1660), Ettmueller (Leipzig, 1675), Christian Lamperti (Merseburg, 1689), Jeronimo Soriano (Saragossa, 1690), John Pechey (London, 1697) and J. J. Loew (Nuremberg, 1699). There is much of pediatric interest in the Maaseh Tuviah of Tobias Katz (1652–1729), which has been described by Levinson.‡ Of these, however, only one need detain us, the *De morbis acutis infantum* of Walter Harris, which became so well-esteemed, that even in the middle of the eighteenth century, it was described as "the best that was ever written on the acute diseases of infants."

Walter **Harris** (1647–1732), of Gloucester, England, was elected fellow of New College Oxford in 1666 and took his baccalaureate degree in 1670. Joining the Church of Rome, he resigned his fellowship and went to study medicine in France, taking his M.D. at Bourges in 1675. Commencing practice in London in 1676, the edict of 1678 compelled him to recant his Catholic professions, after which he was received M.D. at Cambridge. He became an F.R.C.P. in 1682, was twice Harveian orator (1699, 1707), treasurer (1714–17) and delivered the Lumleian lectures at the College of Physicians during

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* Traill, *op. cit.*, pp. 116–120.

† For a detailed account of the pediatric treatises of Ceck (1603) Ferrarius (1604), Jacques Guillemeau (1909), James Primrose (1659), John Pechey (1696) and others, the reader is referred to G. F. Still's essay in the Osler Anniversary Volumes, New York (1919). 1, 177–191.

‡ A. Levinson, Bull. Soc. Med. Hist. Chicago, II (1917–19), pp. 110–118.

1714–17. He became physician-in-ordinary to Charles II (1683) and, after the Revolution, physician to William III, attending Queen Mary in her last illness (1694). He accompanied King William to Holland, and, while there, published, at Amsterdam, his treatise on the Acute Diseases of Infancy (1689), which was reprinted in 1705, 1720, 1736, 1741, 1745, translated into German (1691), French (1738) and twice into English (1742), holding the field until it was supplanted by the English treatise of Michael Underwood (1784). It is not strange that the best pediatric treatise of the seventeenth century was inspired and patronized by its greatest clinician. Harris was a friend and protegé of Sydenham, who once advised him to read Don Quixote in lieu of medical studies. He was far behind Sydenham in capacity for clinical observation, but, he quotes, with pardonable vanity, an utterance of his master: "I think your little book may be of more service to the public than all my own writings." The pathology of Sydenham was the old Hippocratic pathology of coction of the humors and discharge of the *materies morbi;* but Harris affected the acid diathesis of Franciscus Sylvius, *viz.*, that "all the symptoms of gastro-intestinal disorders owe their origin to acid products in the body" (Abt).

Following the Hippocratic reasoning that diseases, different in different localities, are of but one species with one universal cause, Harris reasons that children's diseases are due to the moisture of their constitution ("puerile humidity"), which "is not apt to degenerate into any putrefaction but the acid." Acid eructations, acid stools abound in infancy, and milk itself turns sour and coagulates when heated. "All the symptoms of infants owe their origin to an acid, as their legitimate parent." The concept of infancy is extended beyond Galen's three months to the fourth year, childhood extending to fourteen. Infants fall sick spontaneously and are as easily cured. The directions for diagnosis, as derived from the nurse's observations, are admirably paragraphed. Our author dilates on the "procatartic cause," *i.e.*, hereditary taints in the parents, the depraved appetites of pregnancy, coition during pregnancy, and maternal impressions. Other immediate causes of infantile diseases are catching cold, thickness of breast milk, the dangers of mercenary wet-nurses, and giving infants meat and wine. Wine is, however, recommended for English girls at the appearance of the menses, even before the Galenic fourteenth year. Disordered digestion, rashes, gripes, flatulence, constipation, vomiting, green stools, fever, convulsions, thrush at teething, are all attributed to acidity, "the tragedy in the lower belly."

Fever in children is "an increase of the natural heat." Lean and scrawny infants are most liable to nervous fevers; fat infants abounding with phlegm, with soft heads, are liable to rickets, whooping cough, thrush and King's Evil; children born of sickly hysterical mothers, to depraved appetites. Harris sharply scores the poor therapeutic resources of his contemporaries, who follow the beaten track of the ancients. Even his pattern, Sylvius, is denounced as "the opiate doctor." He ridicules chemical therapeutics as imposing "the impenetrable hardness of metals" upon "the waxen softness of the infantile constitution." "Mindful of acidity," he upholds Sydenham's practice of purging in fevers, but opposes the use of sudorifics (diaphoretics). His recommendation of "testaceous powders" (oyster shells, crab's eyes and claws, pearls, coral, prepared chalk, Goa stone, etc.) as anodynes and "absorbents of acid" held its own in English practice for over a century. A series of shell-powders and pearl juleps is listed. Rhubarb is better than aloes for infants. Cream of tartar must be unadulterated. Bloodletting is only of use in convulsive coughs or fevers with cough. The exhibition of opiates is only permitted in obstinate vomiting. The Turkish practice of giving lemon juice in plague and malignant fevers is praised. Teething, thrush, vomiting, diarrhea, convulsions, smallpox, are all to be treated by "testaceous medicines." The work closes with a series of clinical cases, illustrating this theory. Throughout the entire book, semeiology is presented in a free-hand manner, evidently intended for popular consumption. Walter Harris resembles Galen in his vanity about successful cures. His treatise on the venereal disease anticipates some of the historical views of Sudhoff.

The treatise of Harris is really a racy argument in favor of a certain theory of disease and a certain line of treatment. A far greater name in the history of pediatrics is that of Francis **Glisson** (1597–1677), or Rampisham (Dorsetshire), who described the hepatic capsule investing the portal vein (1654), employed suspension in spinal deformities (1660), introduced the concept of "irritability" as a property of all living tissues (1677) and gave the original and classical account of rickets and its association with infantile scurvy in his "*De rachitide*" (1650).* Rickets, first mentioned in the London Bills of Mortality in 1634, was first described in Daniel Whistler's "*De morbo puerili Anglorum*" (1645),† and further in a tract of John Mayow (1669), and in some 12 inaugural dissertations listed by Meissner (pp. 134–135).

In the pediatric handbook (1609) of Jacques Guillemeau (1550–1612), which contains a strong brief for material breast-feeding, the dependence of kyphosis and bending of the ribs upon faulty nutrition is already recognized even though the condition is not labelled (G. J. Still). The *de morbis infantum* (1674) of Franciscus Sylvius (1614–72), the fourth book of his *Praxis Medica*, and translated into English by Richard Gower (1682), illustrates the ideas of Sylvius about gastro-intestinal acidity as the cause of infantile disease. The only new feature is "green stone with gripes," the green scour of Cheyne.

Of original clinical contributions bearing upon pediatrics, Tobias Cober noted the relation between typhus fever and pediculosis (1606), André de Laurens maintained the contagiousness of scrofula (1609), Felix Platter first described "thymus death" (1614), Francois Citois described "Poitou (lead) colic" (1616), Daniel Sennert (1626) and Sydenham (1675) described scarlatina, the latter giving the disease its name, Höfer described cretinism (1657), Jacob Bontius beriberi (1642) and Porchon described Rötheln as "the purples" (1698).

The great Sydenham left classical accounts of many diseases, notably broncho-pneumonia, pleuropneumonia, dysentery (1672), measles (1675), hysteria (1682) and chorea minor (1686), and paid particular attention to children's diseases in his writings.

C. V. Schneider (1660) and Richard Lower (1672) showed that the nasal secretions (*pituita*) come not from the brain (as hitherto supposed) but from the Schneiderian membranes.

Swammerdam demonstrated that the fœtal lungs will float after respiration (1667), which medico-legal test was successfully applied in a court-room case of infanticide by Johan Schreyer (1681).

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* See Glisson, "De rachitide." London (1650), pp. 285–286, or the English translation, London (1668), pp. 249–250.

† Norman Moore (in St. Barth. Hosp. Rep., London, xx (1884), pp. 71–82) shows that Whistler's essay, while antedating Glisson's by five years, is really based on second-hand information obtained from Glisson himself, and is otherwise valueless. Gee has shown that the Flagellum Angliæ of Garancier (London, 1647) contains nothing on rickets.

The seventeenth century literature of special monographs on pediatrics is considerable. Meissner lists 18 titles on infant nutrition, 69 on monsters, 2 on infantile jaundice, 6 on aphthæ, 25 on infantile atrophy, 5 on dentition, 29 on intestinal worms, 8 on hydrocephalus, 7 on scrofula, Rolfinck (1637) and Wedei (1684) on gibbous spine, 3 on club-foot, and 114 on smallpox.

During the seventeenth century, the plague, leprosy, typhus and typhoid fever, smallpox, influenza, and dysentery were more or less pandemic at intervals, and swept away thousands. Influenza was first reported in America in 1647 (Jacobi). Diphtheria was confined to Spain and Italy. The first American case occurred at Roxbury, Massachusetts, in 1659 (Jacobi). Yellow fever appeared in New York in 1668, but did not reach Europe until the 18th century. Smallpox broke out in Pennsylvania in 1661 and in Charleston, S. C. (1699). Infantile conjunctivitis was first reported in America in 1658 (Jacobi).

THE EIGHTEENTH CENTURY

In the eighteenth century, the age of theorists and systematists, clinical pathology was founded by Morgagni and Matthew Baillie, experimental and pathological surgery by John Hunter, preventive inoculation by Jenner, improved clinical and instrumental diagnosis by Auenbrugger, Martine, and Currie, public hygiene by Frank, electrophysiology and electrotherapy by Galvani and Volta; embryology by Wolff, medical bibliography by Haller. The age was remarkable for clinicians of essentially practical type, and pediatrics, as a part of internal medicine, was consequently forward. The most prominent pediatrists of the eighteenth century were Friedrich Hoffmann, Rosen von Rosenstein, Armstrong, Raulin, Underwood, Mellin, and Struve. The pediatric literature of this period is marked by original clinical observations from actual case histories, with an occasional eye to morbid anatomy.

Friedrich **Hoffmann** (1660–1742), of Halle, a medical graduate of Jena (1682), and one of the most highly esteemed physicians and medical theorists of his time, published a *Praxis clinica morborum infantum* in 1715, which was translated into German (1741) and followed by another treatise on the principal diseases of infants (1747). Hoffmann also left original contributions on infantile atrophy (1702), mesenteric fever (1728), chlorosis (1730), whooping cough (1732), intestinal worms (1734), diseases of the fœtus in utero (1738), and was one of the first to describe rubella (1740).

Nils Rosen von **Rosenstein** (1706–73), born near Gothenburg, Sweden, on February 1, 1706, being intended for the ministry, studied medicine in secret, against the will of his father, and after working and teaching for eight years, followed by three years of extensive travel, he received his medical degree at Hardwick (1731). Attaching himself to the University of Upsala as a teacher, he succeeded Rudbeck as professor of anatomy and natural history in 1740, later filling also the chairs of physiology and practice, with clinical teaching at the bedside. In 1756, he retired to private practice in Stockholm, and died July 16, 1773. He was physician to the king (1735) and archiater (1745), became a member of the Swedish Academy of Sciences (1739) and was ennobled in 1762. In his travels, Rosenstein had met all the medical celebrities of his time, and his ability, rare experience, and amiable disposition made him widely known as one of the best physicians of his period.

He published a compendium of anatomy in Swedish (1738), a treatise on domestic medicine, after the fashion of Tissot's *Avis au Peuple*, and some 50 Latin dissertations on the most varied subjects, such as the recording of clinical cases (1728), purification of water (1736), errors in prescribing (1737), equitation (1738), incipient phthisis (1740), gastritis (1740), the possibilities of plastic surgery (1742, smallpox (1751–4) and infantile epilepsy (1754), but his greatest work is his treatise on children's diseases (1764),* which was preceded by a dissertation on infantile diseases (1754). The pediatric treatise was reissued in 1761 and 1771 and was translated into German (1766), Dutch (1768), English (1780) and French (1780). The German translation passed through six editions. Rosenstein described the first epidemic of scarlatina in Sweden (1742–3), also the symptoms of hyoscyamus poisoning in a boy (1744), in which he was the first, after Galen, to call attention to mydriatics. In the edition of 1771, Rosenstein's treatise consists of 28 chapters, the first on wet-nursing, the rest on costiveness, prolapsus ani and other infantile disorders. Pneumatocele, inoculation of smallpox, inoculation of measles, scarlet fever, whooping cough (chin cough); ague, croup, venereal disease, and vermin are the new subjects featured. It is maintained that a child should be suckled on its mother's own milk, as alien milk may make it sick. Lactation is held to relieve mothers of milk fever and leucorrhea. If a wet-nurse is employed, she must be free from diathetic or venereal disease. The sucking-bottle (biberon), if used at all, must be kept clean. The nurse should be purged with suppositories of honey and olive oil, as active purges will injure the child through the milk. Violent emotions in the nurse will produce convulsions in the child. The breast should not necessarily be given when the child cries, but only when its eyes sparkle with anticipation. A modern note is the warning against the neglect of diarrheas falsely attributed to teething, and the insight into the harmful effects of overfeeding (Heubner). Swaddling is condemned. Nursing by the fire-side is dangerous (burns and CO poisoning). Rosenstein never saw a tongue-tied child. Snipping of the frenum is to him a nurse's trick. Violent rocking causes indigestion and vomiting. The meconium is to be purged out by an artificial nipple steeped in manna and sugar. Gripes must be speedily treated, lest they cause convulsions. In teething, the brains of a hare or other animal remedies are ridiculed, and a wolf's tooth is no better to bite upon than crystal or other hard substance. The different diseases and their treatment are given in great detail. No less than fourteen different species of diarrhea are described. The Chinese and Circassian methods of inoculating against smallpox are given, also the folk-custom of "buying the smallpox." Rosenstein used a preservative pill of calomel, camphor, aloes, and guaiac. The general technique of inoculation occupies a chapter of 35 pages. Francis Home's experiments on inoculating against measles are praised. The true cause of smallpox and whooping cough is "some heterogenous matter or seed, which has a multiplicative power." Immunity after an attack is noted. Water-drinking (especially the mineral water at Satra) and eating fish or raw ham may cause helminthiasis. The history of infantile rickets and of infantile cramp in Sweden is detailed, with many case histories. The work abounds in statistical observations and reasoning drawn from the Swedish bills of mortality.

William **Cadogan** (1711–97) of London, a Leyden graduate of 1737, who became an army surgeon, made a wide reputation by his "Essay on the Nursing and Management of Children" (1750), which passed through 10 editions, and his Dissertation on Gout (1771).

The pediatric essay is well written, full of sound sense, did much to substitute loose clothing for swaddling and was a strong argument in favor of maternal nursing against the spoiling of the child's stomach with panada, caudle, sugared and spiced paps and bread adulterated with alum. Magnesia alba is preferred to the pearl and chalk juleps of Harris. Sensible directions for exercise are given.

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*Rosen von Rosenstein, Underrättelser om barn-sjukdomar och deras bote medel. Stockholm, 1764.

In 1767, George **Armstrong**, a London pediatrist, published "An Essay on the Diseases most fatal to Infancy," which passed through three editions (1771, 1777, 1778) to be enlarged by A. P. Buchan in 1808. In 1769, Armstrong established the first pediatric hospital in England, a Dispensary for Poor Children, which was discontinued in December, 1781, from lack of financial support. It was the only institution in which the children of poor parents were received without letters of admission, in cases of desperate illness. During the twelve years of its activity, 35,000 children were admitted and treated. Armstrong published an account of his Dispensary in 1772, but his philanthropy went unrewarded. He died in obscurity.

His "Essay" is a good example of the judicious, common-sense clinical observation of the English practitioner of the time. He notes the neglect of pediatrics in his period, the common byword being that "The best doctor for a child is an old woman." Even John Hunter maintained that nothing can be done for children when they are ill. Armstrong denounces the common neglect of children's diseases, both by parents and practitioners, particularly the impotent plea that children cannot tell of their ailments and doctors are incompetent to prescribe for them. He describes 20 infantile diseases, omitting the acute fevers for lack of ripened personal experience with them. He makes much of "inward fits" (wind-colic) and the hectic fever of teething as new diseases. Constipation is "dry gripes" and diarrhea (cholera infantum) "watery gripes." The chapter on hydrocephalus internus contains three cases, successfully treated, by Matthew Dobson, John Hunter, and Armstrong. Separate chapters are devoted to ophthalmia, lippitudo (blear-eyes), leucoma and tumors after smallpox, and there is a chapter on the treatment of incipient cataract. The chapter on scrofula emphasizes the value of sea-air and sea-bathing for city children and of a dry inland climate for scrofulous children from the coast. Armstrong's favorite remedy is "a milk puke of antimonial wine." He upholds the practice of emesis in infantile complaints, but urges that the bowels should be evacuated before emesis. The importance of early exercise as a preventive of infantile disease is emphasized. the work winding up with some rules on nursing. He first described congenital pyloric stenosis (1777).

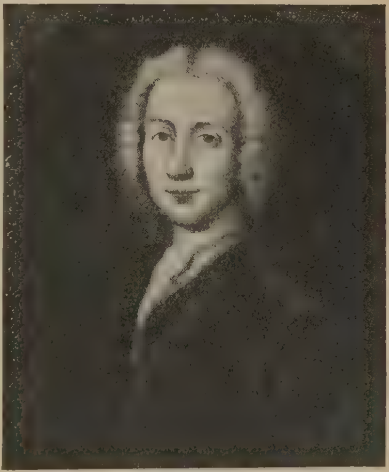

Fig. 8.—Robert Whytt (1714–66). (Courtesy of Dr. John Ruhräh, Baltimore.)

In the same year in which Armstrong's Essay appeared, Robert **Whytt** (1714–66) of Edinburgh, eminent in the physiology of the brain and spinal cord, published his "Observations on the Dropsy in the Brain" (1768), which contains the classical account of **tuberculous meningitis.**

Some features of this disease had been vaguely noted by the ancients. Thomas Willis observed the placques and tubercles (1682); Petit confused acute and chronic hydrocephalus (1718); Boissier de Sauvages gave a good description (1763); but Whytt's account individualized the clinical picture, and nothing further was done until Senn of Geneva located the lesion in the pia mater, calling the disease meningitis (1825), W. W. Gerhard established its tuberculous nature (1834) and Rilliet and Barthez completed, in 1843, the differential diagnosis (Ruhräh).*

In the same year, Joseph **Raulin** (1708–84), a provincial French practitioner who came up to Paris about 1750, published a two-volume treatise on the conservation of infancy (1768), which was reissued in three volumes in 1779, and is now valued highly for its historic sidelights on the methods of dry-nursing.

Michael **Underwood** (1736–1820), of Surrey, England, studied at St. George's Hospital (London) under Cæsar Hawkins, saw something of the practice of John Freke, and finished his medical education in Paris. He practised surgery in Great Marlborough Street, and after admission as licentiate of midwifery at the College of Physicians (1784), became attached to the British Lying-in Hospital, and attended the Princess of Wales at the birth of Princess Charlotte (January 7, 1796). He was the last "man midwife." In 1783–8, he published a treatise and some surgical tracts on ulcers of the legs, and, in 1784 his "Treatise on the Diseases of Children." This book took the place of Walter Harris's treatise and passed through several editions, the last being much enlarged by John Bell and Marshall Hall (1842).

The first edition contains the earliest account of **poliomyelitis.** The book, dedicated to the Queen, is written for the laity as well as the profession. Technical terms are avoided. Our author apologizes for his prolixity of style, preferring to make his meaning plain even at the expense of concision. He laments the neglect of the study of infantile diseases, and that, in the past, "little more had been attempted than getting rid of the wild prejudices and anile prescriptions of the older writers." The dangers of high infantile mortality to the body politic are already signalized. Underwood combats Armstrong's idea of giving an emetic to evacuate the meconium and hisgeneral preference for antimonial wine over the chalk juleps and absorbent powders of Walter Harris. The new disorders described are those arising from malformations of the heart, "red gum," milk blotches (crusta lactacea), "skin bound" (sclerema, the taut, waxy cold skin of Andry and Tenon), mesenteric fever, marasmus, cardialgia, chicken-pox (Heberden), spasmodic cough, seven-days disease (tropical convulsions), shingles, ringworm, cataract, sty, deafness, gangrenous erosion of the cheeks, psoas abscess, Pott's disease, poliomyelitis, whitlow, boils, chilblains, burns and scalds, tongue-swallowing, epistaxis, umbilical hemorrhage, hydrocele, retained testis, tumefaction of the prepuce, vaginal discharges, poisonous bites, hernia cerebri, tumors of the scalp, spina bifida, harelip, and nævus. Ranula, siriasis, macies and other diseases of the older writers are reviewed, and the chapters on luxations and fractures, varus and valgus in children are the first after Felix Würtz. The book concludes with a chapter on nursery hygiene, or the "non-naturals" (food, air, sleep, etc.), including directions for reviving still-born infants, the necessity of hardening by inuring to cold, and the need for definite exercise in infants. The concluding section on the "passions of of the mind" is an early essay in infant psychology.

A remarkable medical polyhistorian of the Old Vienna School was Joseph Jakob von **Plenk** (1738–1807), who wrote systematic treatises on obstetrics (1769), surgery (1769–83), anatomy (1776), dermatology (1776), ophthalmology (1777), dentistry (1778), bromatology (1784), toxicology (1785), botany (1788–98), pharmacy (1799–84) and pediatrics (1807).* His *Doctrina* contains a good classification of infantile diseases, treats of asphyxia neonatorum, chorea, tabes dorsalis, gonorrhea, infantile syphilis, pediculosis, malocclusion (dentitio obliqua), and many other complaints in remarkably terse paragraphs, with many prescriptions, concluding with a plate of a deaf and dumb alphabet. Plenk's books, any of them, would be a treasure-trove for medical examiners in easy Latin. He made a reputation by treating infantile syphilis with "mercury-gum," a suspension of mercury in gum arabic.

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* J. Ruhräh, Med. Library & Hist. Jour., Brooklyn, ii (1904), pp. 153–165, port.

Gerhard **van Swieten** (1700–1772), leading physician of the Old Vienna School, in his Commentaries on Boerhaave's Aphorisms (1743), contributed notably to the rational pediatrics of his time, particularly in regard to the care and hygiene of infancy. A miscellaneous author of the same type, but less profound, was Christoph **Girtanner** (1760–1800), of St. Gall, Switzerland, a vain, disputatious and somewhat superficial writer, who was one of the opponents of the Brunonian theory of disease, and the author of a three-volume historical essay on venereal diseases (1783–9). He published (1794) an essay on children's diseases,† which, in the opinion of contemporary pediatricians, is showy and specious. Christoph Jakob **Mellin** (1744–1817), a Jena graduate of 1766, published on account of the epidemic of whooping-cough at Langensalza in 1768–9 (1770), and a pediatric treatise *Der Kinderarzt* (1787). The famous Christoph Wilhelm **Hufeland** (1762–1836), of Berlin, published two tracts, addressed to mothers, on the hygiene and physical education of children (1794–9) and a treatise on the hygiene and diseases of the fetus in utero (1827). A Handbook of Children's Diseases, for parents and preceptors, was published by Christian August **Struve** (1767–1807), of Görlitz, in 1797.

The pioneer of **school-hygiene** was the celebrated Johann Peter **Frank** (1745–1821), in his "Complete System of Medical Polity" (1777–88), the first systematic treatise on public hygiene, which contains separate chapters on the hygiene of infancy, lactation, wet-nursing, foundling asylums, the overtaxing of childhood and the hygiene of education. The chapter on school-hygiene contains practically everything brought out later by Virchow and Hermann Cohn. The proper lighting, heating and ventilation of the school-room, the proper slanting and adjustment of desks and benches in relation to visual requirements, are all features of this wonderful book.

The miscellaneous literature of pediatrics in the eighteenth century is extensive and difficult to classify. The reader is referred to the arrangements by subjects in Meissner's sterling bibliography. Nearly every important physician of the period wrote something on pediatric subjects. Stahl wrote on the requisites of a good wet-nurse (1698), worms (1698), ascites (1702), diseases of children (1705), medical gymnastics (1708), smallpox and measles (1709) and cachexia (1710); Haller on monsters (1745–53), spinal deformities (1748–9) and congenital hernia (1749); Roederer on smallpox (1756), apparent death (1760), infantile atrophy 1758), tænia (1760) and rickets (1788); Joh. Peter Frank on education (1766), rickets (1788) and gastric fever (1799); Wrisberg on fetal respiration (1763), monsters (1791–9), undescended testicles (1799), apparent death (1780) and inoculation; Baumes on convulsions and colic (1781), epidemic jaundice (1788–1806), and scrofula (1789–1805).

In 1774–6, Hugh Downman (1740–1809), a physician of Exeter, England, published "Infancy: a Poem," in three parts, which was reprinted several times down to 1809.

The literature of **smallpox, variolation and vaccination** is enormous. In the period preceding the publication of Jenner's Inquiry (1798), variolation or inoculation, introduced from the Orient by Timoni (1713) and Pilarini (1715), was taken up by Lady Mary Wortley Montagu in England (1721) and by Zabdiel Boylston in Boston (1721), and after a period of stagnation (1727–43), was revived by the success of Kirkpatrick in South Carolina (1743), Robert and Daniel Sutton (1760) and William Watson (1768) and Angelo Gatti (1769) in Paris, and actually attained the status of scientific preventive inoculation during 1764–98. Variolation is preventive inoculation against smallpox by means of virus taken from the human subject. In folk-medicine, the end was attained by the East-European custom of "buying the smallpox," *i.e.*, by bringing coins moistened with virus from the scabs, purchased in open market, into contact with skin. The usual procedure in the middle of the century was inoculation by puncture or incision, preceded by blood-letting and purging. Sutton substituted a sensible strengthening regime for this depletion of the patient, and Kirkpatrick attenuated the virus by passing it through several human subjects, diluting with water, etc. Gatti showed that apparent reinfection was due to mixed infection of other exanthems (scarlatina, measles). In this period of experiment in preventive inoculation prior to Jenner, children played a prominent part. Timoni inoculated his daughter (1707), Lady Montagu her infants (1718–21), Boylston his son (1721), Dimsdale made a fortune by inoculating Catherine of Russia and her son (1768), and Ingen-Housz inoculated three of the royal family of Austria (1768), after preliminary experiments upon 200 children of the Viennese suburbs. Jenner made his first experiment in vaccination upon a country boy, James Phipps, on May 14, 1796. The great danger of variolation was that the inoculated person became, through the scab, a true smallpox carrier, and the inoculation was sometimes fatal. Vaccination, with little mortality and no possibility of convection, carried the day, and variolation was declared a felony by Act of Parliament in 1740.*

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* J. J. von Plenk, "Doctrina de cognoscendis et curandis morbis infantorum," Vienna (1807).

† C. Girtanner, "Abhandlung über die Krankheiten der Kinder." Berlin 1794).

Of the many infantile diseases which were first described and individualized by the clinicians of the eighteenth century, **diphtheritic croup,** variously known as angina puerorum, angina polyposa, angina maligna, angina suffocativa, angina membranacea, syncope angionosa, cynanche trachealis and cynanche stridula, became better understood through the careful accounts of John Fothergill (1748), J. B. L. Chomel (1749), John Huxham (1757), Francis Home (1765), and Samuel Bard (1771). In 1736, John Freke described myositis ossificans progressiva in a boy. Francis Home (1719–1813) made his experimental inoculations of **measles** in 1759. John Millar (1733–1805), in his "Observations on the Asthma and on the Hooping Cough," described **thymic asthma** (1769). J. Z. Platner reviewed the Hippocratic doctrine of the tuberculous nature of gibbous spine, with an interesting plate (1744). **Pellagra** was described by Gaspar Casal (1735–62) and Francis Thierry (1755) and named by Francesco Rappoli (1771). Robert Hamilton emphasized the orchitic lesion in **mumps** (1761). Mestivier operated for **appendicitis,** and described the true lesion, from a pin (1759). Heberden described **varicella** (1767), Whytt **tuberculous meningitis** (1768), John Rutty **relapsing fever** (1770), Percival Pott and J. P. David pressure paralysis from **spinal caries** (1779), Sir George Baker lead-poisoning in children (1784), Hezekiah Beardsley **congenital pyloric stenosis** (1788), Malacarne (1788) and Foderé **goitre** and **cretinism** and Soemmerring **achondroplasia,** with a fine plate (1791). John Machin (1753), Henry Baker (1753) and Tilesius (1802) traced ichthyosis hystrix through successive generations of the Lambert family.

American pediatrics in the 18th century was more remarkable for original descriptions of diseases than for definite contributions to the subject.

The graduating thesis of the celebrated Charles Caldwell (1772–1852) at the University of Pennsylvania (1796), attempts to show that internal hydrocephalus, diphtheria (cynanche trachealis) and infantile diarrhea were only symptomatic of fever in infants (S. S. Adams).† The best individual contribution is the section on diseases of children in Lionel Chalmers' "Account of the Weather and Diseases of South Carolina" (1776), which treats of worms, convulsions, thrush, otorrhea, catarrhal peri-pneumonia, nervous asthma, quinsies, angina, and whooping cough (Jacobi). The most remarkable things were the long series of American tracts on smallpox, inoculation and vaccination (1721–1802), the accounts of diphtheritic and other anginas by William Douglas (1736), Cadwallader Colden (1757), Samuel Bard (1771), Jabez Fitch (1736), I. Dickinson (1740), Peter Middleton (1780), Richard Bayley (1781), of malignant pleurisy by John Bard (1749), of yellow fever by John Bard, Colden (1743), Mitchell (1741), William Currie (1792), Benjamin Rush (1796) John Lining (1799), and of congenital hypertrophic stenosis by Hezekiah Beardsley (1788). **Samuel Bard's** account of diphtheria was translated by Bretonneau in his great work of 1826, highly praised by Jacobi for its descriptions of the pharyngeal, tracheo-laryngeal, and cutaneous manifestations, and pronounced "An American classic of the first rank" by Sir William Osler, who also reprinted Beardsley's paper on congenital pyloric stenosis in 1903. Benjamin **Rush** (1745–1813), the greatest American clinician of his time, described cholera infantum (1773), dengue (1780), influenza in children (1789–91), and the thermal fever occasioned by the drinking of cold water.

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* A. C. Klebs, "Die Variolation im achtzehnten Jahrhundert." Giessen (1914).

† S. S. Adams, The Evolution of Pediatric Literature in the United States, Tr. Am. Pediat. Soc. N.Y., IX, (1897)., 5–31.

Jacobi, in his "History of American Pediatrics before 1800,"* says that **measles** appeared in New England in 1713, with many later outbreaks; epidemics of **influenza** from 1647 to 1789 were described in old records; **scarlatina** broke out in Philadelphia and Salem, Mass., in September, 1783, through New England in 1784, these epidemics lasting five years, and again in Philadelphia (1789–91) and the Northern States (1792–3). **Diphtheria,** first reported in New England in 1659, appeared at Kingston, N. H., in 1735–6, as the angina ulcusculosa" of William Douglas.

The rate of **infant mortality** was dreadfully high in the 18th century.

Hand-feeding had come into fashion, and Sir Hans Sloane stated that the mortality of dry-nursed infants was nearly three times that of the breast fed. When patients at the British Lying-in Hospital were required to suckle their own infants, the mortality fell to 60 per cent. "Death from want of breast milk" was the common entry in hospital records.

Of 10,272 infants admitted to the Dublin Foundling Hospital during 21 years (1775–96), only 45 survived, a mortality of 99.6 per cent. Of 31,951 infants admitted to the Paris Foundling Asylum during 1771–77, 25,476 (80 per cent.) died before the end of their first year (Forsyth). From tables constructed from the London Bills of Mortality covering the 100 years ending 1829, the death rate per 100 of children under 5 was: 1730–49 (74.5); 1750–69 (63); 1770–89 (51.5); 1790–1809 (41.3); 1810–29 (31.8) (Edmonds).† Malthus said that to multiply infant hospitals and foundling asylums was the surest means of checking the growth of the population. *Ici on fait mourir les enfans* was the inscription proposed by a French critic for the Parisian institutions of this kind. Outside the hospitals, the evils of baby-farming and of mercenary wet-nursing (in France) were prominent factors. The English wet-nurses of the period got 25 guineas a year, which led many young women to have illegitimate children, who were abandoned at foundling hospitals or died through baby-farming. In France, the evil was the same.

In Georgian England, mixed feeding in the shape of water-pap (moistened bread), baked flour pap, weak-broth, beef-tea, bread panada sweetened with Lisbon sugar, French bread, Uxbridge rolls, and even the minced meat of turtle-doves, larks, thrushes, ortolans and chickens, was preferred to cow's or goat's milk. Of these infant foods, William Cadogan observes in his Essay on Nursing (1750) that "their paps, panadas, gruels, etc., are generally enriched with sugar spice or a drop of wine; neither of which they ought ever to taste," and he adds that "The London bakers are suspected of putting alum into their bread, which would be very pernicious to infants; therefore rusks, or the biscuits called tops-and-bottoms, or rice may be used instead of it." Small beer was given to children, and even Underwood recommended a little red wine, as preventing rickets in infants learning to walk. Struve recommended three beaten yolks of eggs in a sweetened quart of beer for infants after weaning.* Of suckling apparatus, the cowhorn (known on the continent from the 13th century) became common in England about 1783 and was praised by Heberden. The glass nursing bottle, the pap-boat and pap-spoon did not come into vogue until the 19th century. On the continent, as we have seen, all these methods had long been known. Porcelain flasks are mentioned by Raulin (1769). Retort-shaped glass flasks were introduced by Baldwin (1781). Raulin and Rau also recommended boat-shaped cups and flat glasses with beaks, shaped like a Roman lamp. The boat was first mentioned in England by Armstrong (1792) and held 3–4 fluid ounces. Although ridiculed by Girtanner, who inquired whether the "boat" was a shallop or a warship, this form survived as the "Vienna ship" of Rau, and was used even when Ammon, in 1882, condemned it as making the child swallow rather than suck. The "Cadogan cans" were used in England, but boats and cans proved dangerous when made of tin. Cone-shaped glass flasks, provided with a nipple, were used up to 1875. Peter Camper mentions a tube reaching to the bottom of the bottle (1777), a precursor of the modern sucking tube (Brüning).†

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* A. Jacobi, Collectanea Jacobi, New York, iii (1909), pp. 1–40.

† J. R. Edmonds, Lancet, London, i (1835–6), pp. 690–694. Cited by A. K. Chalmers.

In 1761, Jean-Jacques **Rousseau** published *Émile*, a tract on the education of children, which was condemned and denounced by the Archbishop of Paris for its irreligious tendencies (1762). The part which immediately concerns us is the long introductory passage in Book I, which deals with the hygiene, and nutrition of infancy. In this passage, which is virtually a popular treatise on pediatrics, the dangers of mercenary wet-nursing and swaddling infants are set forth, women are exhorted to nurse their own children, and along with much that is silly and inept, there is much that is sound and sensible. The book is a tedious one to read, on account of its multifarious rhetorical declamation and the foolish, false sentiment of the period. Rousseau, himself, is said to have consigned his five illegitimate children to a foundling asylum. He was a striker of attitudes, his life, as Carlyle said, "a long soliloquy." Medicine, in particular, he ridicules as a useless fashionable cult, "the amusement of the idle, aimless people." But his revolutionary ideas about "return to nature" appealed to the people of his time, and the centric theme of his argument—"*point de mère, point d'enfant* did much to awaken French mothers to the obligation of breast-nursing and caring for their own offspring.

Émile engendered a large crop of literature on the dangers of mercenary wet-nursing and swaddling, such as the *Avis aux mères* of Madame Le Rebours (1767), the *Dangers du maillot* of Lascazes de Compayre (1778), the *Observations sur l'allaitement des enfants* of Levret (1781) and the pamphleteering of F. A. Weiz (1782) and K. Strack (1782–9) on the trade-tricks of wet-nurses. The *Nomothelasmus* of Geronomino Mercuriali was fished up and printed at Padua in 1788. Rousseau's propagandism against wet-nurses which had even been preceded by Linnaeus (*Nutrix noverca*, 1762), and others, found its echoes at Vienna in the letters of Maximilian Stoll (edited by Eyerel, 1788), in the pamphlets of Cadogan

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* D. Forsyth, Proc. Roy. Soc. Med., London, iv (1910–11), Sect. Dis. Child., pp. 121–126.

† H. Brüning, "Geschichte der Methodik der künstlichen Säuglingsernährung." Stuttgart (1908), pp. 93–103.

(1750) and Benjamin Lara (1794) and in Wilmington in "The Female Monitor" of H. Smith (1801).

While children were cleverly and effectively portrayed by Reynolds, Gainsborough, Raeburn and other painters of the period, the only picture of special pediatric interest is the copperplate from Hogarth's "Mariage à la Mode" (Plate III), representing a dissolute parent bringing his syphilitic child to a quack. That the primitive preference for male offspring was still ascendant is evidenced in the engraving of J. J. Moreau the younger, entitled "*C'est un fils, Monsieur!*" The glorification of the male was, in fact, to reach its apogee in the biological writings of the Bavarian naturalist Lorenz Oken (1779–1851), who declared that "Ideally, every child should be a boy." Lecky, in his histories of England and Ireland in the eighteenth century records that infanticide was common in Scotland and very rare among the Irish in this period. Of cruelty to children, an outstanding instance may be recalled in the childhood of Frederick the Great and his sister, the Margravine of Bayreuth. Had the father of these children been less of a brute, the present European war might never have occurred.

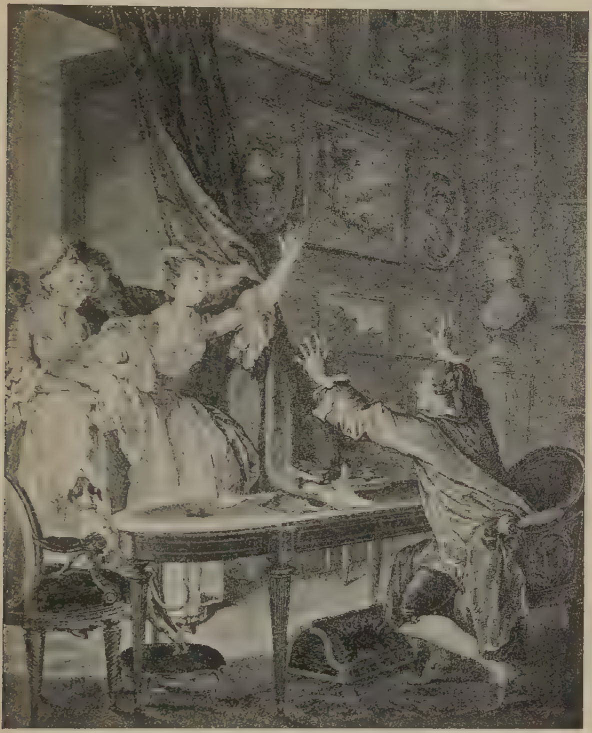

FIG. 9.—J. M. Moreau *le jeune*: "C'est un fils, Monsieur!" (Preference for male offspring in the 18th century.)

In the eighteenth century blind beggars were objects of ridicule. They were tricked out with asses' ears, peacocks' tails, and pasteboard spectacles to be utilized in burlesque concerts for popular amusement in public places. Diderot was thrown into the Bastille for suggesting that they might learn to read and write by the sense of touch. Rousseau suggested a system of embossed printing for the blind, and Valentin Hauy (1745–1822) founded an *Institute Nationale* for young blind persons in 1785, which was successful. The *Lettres sur les aveugles* of Diderot (1749) and the *Essai* of Hauy (1786) are the early landmarks of this movement. The pioneer of **deaf-mute instruction** in France was the Abbé Charles-Michel de l'Epée (1712–89) who founded the first school for deaf-mutes in Paris (1775), published a method of instruction (1784), and left an unfinished dictionary of the deaf and dumb signs, which is said to have been completed by his successor, the Abbé Cucurron Sicard. In America, the earliest pioneer of the deaf-mute instruction was Francis Green (1742–1809), of Boston, in his *Vox oculis subjecta* (London, 1783).

THE NINETEENTH CENTURY

In reviewing the late pediatric literature of the nineteenth and twentieth centuries, no attempt will be made to analyze or criticize the basic texts. To furnish a critical inventory of the contents of the older writings is conceivably and admittedly a function of bibliography. To render a detailed account of the vast pediatric literature of recent times is a fitting task for some future specialist in children's diseases. The outstanding text-books before the time of Heubner and Finkelstein were those of Billard, Rilliet and Barthez, Bouchut, Charles West, Bednar, Henoch, Gerhardt and Rotch, with the larger systems of Gerhardt, Keating, Starr, Pfaundler and Schlossmann, Grancher and Comby, Brüning and Schwalbe. In England, Underwood held the field up to the time of Charles West. The names of Bednar and Henoch mark the rise and predominance of modern German influences. American pediatrists, before the advent of the metabolists, have pursued an independent course. The most favored treatises have been those of J. Lewis Smith, Jacobi, Rotch, and Holt. In this period, infantile surgery and orthopedics became distinct specialties; the movement for the hygienic inspection of schools and school children was inaugurated by Virchow, Chadwick, and Hermann Cohn; juvenile anthropometry, ethnology, psychology, and criminology began to be studied; and the interest in infantile mortality as a phase of national depopulation was the starting point of the new social science of infant welfare. The spirit of the eighteenth century still informs the pediatric literature before the time of Billard, particularly in the remarkable books of Cheyne, Heberden, and John Clark.

John **Cheyne** (1777–1836), of Leith, Scotland, a medical graduate of Edinburgh (1795), entered the army as a surgeon of artillery. He led a frivolous, dissipated life until he settled down to solid practice at Leith Fort in 1799, devoting himself to infantile and contagious diseases. In 1809, he settled in Dublin, became physician to Meath Hospital (1811) and physician general to the forces in Ireland (1820), which was then esteemed the highest medical honor in that country. In 1802–8, he published his Essays on the Diseases of Children, dedicated to John Rollo, and in 1809 his classic on "The Pathology of the Membranes of the Larynx and Bronchia," beautifully illustrated with colored plates by Charles Bell. In 1821, he described the Dublin fever epidemic of 1817–19. During 1810–11, he made only three guineas in practice, but at the height of his career he commanded £5000 yearly. His health failing in 1825, he retired to his estate at Sherington, Buckinghamshire, and died on January 31, 1836, leaving a posthumous essay on insanity (1843), prefaced by an autobiography. Cheyne's pediatric essays comprise three studies of cynanche trachealis (croup), the bowel complaints of children, and acute hydrocephalus. These are scholarly performances, replete with historical details and original clinical histories with postmortem findings. The essay on bowel complaints is devoted to biliary disorders, in particular, infantile jaundice and the "green scour" (green stools with griping convulsions) and the disease called "weaning brash" in Scotland, or *atrophia ablactorum* (green stools with cachexia). The essay on hydrocephalus acutus, dedicated to Charles Bell, is a continuation of the monograph of Whytt, and sharply criticizes the views of Benjamin Rush. Case histories and autopsies are carefully recorded.

In 1803–12, Karl Bernhard **Fleisch** (1778–1814), of Cassel, published a four-volume Handbook of Children's Diseases containing a series of excellent bibliographies, which undoubtedly constitute the germ of Meissner's chronological lists of 1850. Fleisch is said to have anticipated Czerny in prescribing long pauses between the suckling periods of the nursing infant.*

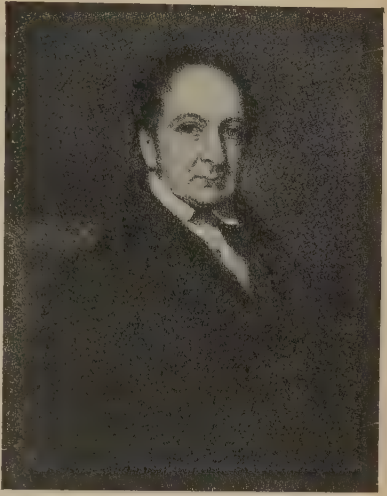

FIG. 10.—John Cheyne (1777–1836).

William **Heberden** (1767–1845), of London, son of the greatest English clinician between Sydenham and Bright, was an Oxford graduate of 1795, physician to St. George's Hospital (1793–1803), and physician to the King and Queen. He attended George III in his last illness. The younger Heberden inherited his father's classical tastes, and made translations of Cicero's Letters and Plutarch on Brotherly Love. In 1804, he published a Latin Epitome of pediatrics,† which he himself translated into English (1805). Heberden's Epitome, the work of one of the ablest Greek and Hebrew scholars of his time, is of all pediatric treatises the most remarkable for classic purity and simplicity of style. In a tiny volume, the size of a child's primer, the hygiene and therapy of infancy and some 52 infantile disorders are set forth in 61 brief chapters, which have all the terse quality of the Hippocratic aphorisms. The very titles—"still-born," "wind on the stomach," "locked jaw," "watery head," "sore ears," "scald head"—suggest the clinician's preference for the plain English of every day practice. Each chapter goes straight to the point, with nothing of the circumlocution of Harris or Underwood. This unpretentious booklet forms a stable bridge between the pediatrics of yesterday and of classical antiquity.

Adolph **Henke** (1775–1843), a famous medical jurisconsult of Erlangen, published a Handbook of Pediatrics (1809), which reached its fourth edition in 1837, a Pocketbook for Mothers (1810), and monographs on developmental diseases (1814), internal inflammation in infants (1817) and pulmonary docimasia (1821).

John **Clarke** (1761–1815), of Wellingborough, Northamptonshire, lecturer on midwifery at William Hunter's school in Windmill Street and at St. Bartholomew's Hospital, was the leading obstetrician of London after Hunter's day, but later devoted himself to a West End practice in gynecology and pediatrics. He published two volumes of obstetric essays (1788–93), and in 1815, his "Commentaries on some of the most important Diseases of Children" (Part I). The diseases featured are disorders of dentition, convulsions, phrenitis, idiocy, paralysis, and epilepsy. These Essays contain the first account of laryngismus stridulus and its association with tetany (pp. 86–97).

John Bunnell **Davis** (1780–1824), being forcibly detained in France by Napoleon, took his M.D. at Montpellier (1803), after which he was released through Corvisart's generosity. Returning to England, he took another M.D. at Edinburgh (1808), and after serving as an army surgeon at Ipswich, settled in practice at London (1816), where he helped to found, on St. Andrew's Hill, the Universal Dispensary for Sick and Indigent Children (1816), the first institution of its kind. Davis's Annals of this Dispensary (1821), during the four years of its activity, is perhaps the first report of a children's hospital. He published a Cursory Inquiry into the principal causes of mortality in children (1817), in which he was the first to advocate visitations of trained nurses for instructing ignorant and indigent mothers in the art of infant nutrition and hygiene.

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* Langstein and Meyer, "Säuglingsernährung und Stoffwechsel." Wiesbaden (1910), p. 54, footnote.

† Heberden, "Morborum puerilium epitome." London (1804). "Epitome of Infantile Diseases." London (1805).

A great step forward was taken when Pierre **Bretonneau** (1771–1862), the eminent clinician of Tours, published his monographs on the contagious nature of typhoid fever (1819–29) and diphtheria (1826). Bretonneau described and understood the lesions in Peyer's patches (1820), predicted that typhoid fever would some day be distinguished from typhus (1821), and clearly stated the doctrine of specificity in disease (1826–55). He was a kind of specialist in diphtheria. In his monograph of 1826,* he synthetizes all the diseases described by so many various names under one generic term "*diphthérite*," which he introduced, elucidates its pathology, describes the cutaneous and vulvar forms and concludes with historical extracts from Ghisi (1740), Samuel Bard (1771) and the older writers. This book contains the first successful case of tracheotomy in diphtheria, which Bretonneau performed on the child Elizabeth de Puységur, on July 1, 1885,† after five successive failures.

Johann Christian Gottfred **Joerg** (1779–1856), a Leipzig M.D. of 1805 and a pupil of the obstetrician Boër, wrote much on gynecology and obstetrics, early orthopedic treatises (1810–12), a handbook of pediatrics (1826) and a monograph on pulmonary diseases from imperfect respiration in the newborn (1832).

Joerg's pupil, Friedrich Ludwig **Meissner** (1796–1857), who graduated in medicine at Leipzig (1819), erected an obstetrical polyclinic there in 1838 and made a great reputation in obstetrics and gynecology. He published a work on superfœtation (1819) a two-volume treatise on pediatrics (1828, 3d ed. 1845) and six volumes of "*Forschungen*" (1826–33), three of which are devoted to a review of pediatric literature from 1801 to 1832. This led to his invaluable *Grundlage* or bibliography of pediatrics (1850),‡ which consists of a strictly chronological arrangement of books and monographs by subjects, under 90 subdivisions, in other words, a miniature Index Catalogue of pediatric literature from 1472 to 1849.

In 1828, Frederick **Corbyn,** a surgeon in the Bengal Army, and editor of the *Indian Journal of Medical Science* (1835–42), published his valuable work on the management and treatment of infantile diseases in India, illustrated by interesting tinted plates. The subject was admirably summarized in a little book of pocket size, the "Hints" (1844) of Henry Hurry **Goodeve** (1807–84), another Bengal Army surgeon, which has been a vade-mecum in Indian pediatrics ever since, reaching its eighth Calcutta edition in 1886. Another treatise on tropical pediatrics was that of the anthropologist F. A. C. **Waitz** (1798–), of Samarang, Java, published simultaneously in Dutch and English (1843, 2d ed., 1866). This was followed by the treatises of S. C. Amesburg (1886), G. Montagu Harston (1912), and others.

In 1833–37, the Austrian Army surgeon Franz Josef **Mezler** von Andelberg (1787–1858) published a valuable collection of pediatric essays,§ selected from the best writers, such as Bischoff on the examination of the sick child, Fenner on pediatric etiquette, Billard on the semeiology of the infant's cry, Hufeland on general principles, fetal diseases and cephalhematoma, Guibert on pericarditis, and Basedow on psorophthalmia.

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* Bretonneau, "Des inflammations spéciales du tissu muqueux et en particulier de la diphthérite." Paris (1826).

† Bretonneau, *op. cit.*, pp. 300–325.

‡ F. L. Meissner, "Grundlage der Literatur der Pädiatrik." Leipzig (1850).

§ Mezler, "Sammlung anserlesener Abhandlungen über Kinderkrankheiten." Prague (1833–7).

The most important pediatric treatise of this early period was that of Charles-Michel **Billard** (1800–32) of Pelouaille, France, who studied medicine at the École secondaire of Angers (1819–23) and came up to Paris in 1824, having acquired the funds by a prize essay on the gastro-intestinal mucous membrane (1825). He was very poor, had to eke out his living by translations, journal articles and other hack-work, and did not get his medical degree until 1828. In the same year he published his treatise on the diseases of newborn infants and sucklings,* with an atlas, (1828, 3d ed. 1837), which was translated into German by Meissner (1829).

This work, the fruit of Billard's internship at the Hospice des enfants trouvés (1826–28), where he made many autopsies, was inspired by his reading of Morgagni, and indeed, is eminently representative of the French medicine of Bichat's and Laënnec's day, in which clinical notations were correlated with autopsy findings. It is, in fact, the first pediatric treatise in which a uniform classification of diseases is attempted from a definite standpoint, *viz.*, that of the pathological lesion. The book begins with a careful consideration of the attitudes, coloration of the skin, height and weight, semeiology of crying, facial expression, and pulse in the newborn. The diseases are classified under the following categories: skin (including exanthematous fevers, cancer, leprosy, anthrax, etc.), digestive apparatus, viscera, air passages, circulation, cerebro-spinal system, locomotive system, generative organs, lymphatics, eye, infantile jaundice, alterations of the blood, abnormities and congenital diseases, with medico-legal considerations, and 87 case histories. This is the first classification of infantile diseases of any importance, for many titles listed in the older treatises are not diseases but symptoms. To the second and third editions, Billard's graduating dissertation on the jurisprudence of viability (1828) was added. The work shows considerable research in foreign literature, its author having learned German, English and Italian in order to write it. After its publication, with a brilliant Parisian career in prospect, Billard, a modest nature, returned to Angers with his wife and child, and died of phthisis on January 31, 1832.

The microscopist Alexandre **Donné** (1801–78), of Paris, who first observed the blood platelets (1842), published an important treatise on milk (1837), with plates, and two books of advice (*Conseils*) to mothers and families on the rearing of infants and children (1846, 1864), all of which were translated into German.

Francois-Louis-Isidore **Valleix** (1807–55), of Toulouse, began the study of medicine at Paris in 1826, became interne at the Children's Hospital (1830) and graduated with a dissertation on slow asphyxia in the newborn (1835). He later served at the Bureau central (1835) and other hospitals, and died in 1855 of diphtheria, contracted while treating a sick child. During his student days in hospital, he gathered the materials for his *Clinique des malades des enfants nouveau-nés* (1838), which follows the tendency established by Andral (*Clinique médical*, 1829–33), carried to the highest point of perfection by Trousseau, and latterly revived by Richard Cabot, Morse, and others, *viz.*, the exposition of the data of internal medicine by means of clinical case histories, rather than by a formal text-book. This tendency characterized the first attempt at a pediatric periodical, the *Clinique des hôpitaux des enfans*, (1811, 1841), as also V. Stöber's *Clinique* from the pediatric section of the Strassburg Faculty (1841), the *Clinique* of A. Becquerel and Vanier (1843–4), the reports from the children's hospitals at Frankfort and Dresden (1845–6), and the later clinical collections of Rittershain and others. Valleix also published a treatise on neuralgia (1841), in which his name is eponymically preserved in "Valleix's points."

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* Billard, "Traité des maladies des enfans nouveaux-nés et à la mamelle." Paris (1828).

The three outstanding pediatric text-books after the time of Billard were those of Rilliet and Barthez, Bouchut, and Charles West. Frédéric **Rilliet** (1814–61), of Geneva, began his medical studies in Paris (1833), and, with his friend Antoine-Charles-Ernest **Barthez** (1811–91), a Paris graduate of 1839, turned his attention to pediatrics. He graduated with a dissertation on typhoid fever in children (1840), and later returned to Geneva, where he described the local epidemics of measles (1847), mumps (1850) and cholera (1856). Before graduation, he had begun, with Barthez, the famous *Traité clinique et pratique des maladies des enfants*, which, after seven years' work, was completed in three volumes (1838–43), crowned by the Academy of Sciences and Academy of Medicine, authorized by the Council of Public Instruction, and passed through three editions, the third (1884), being completed by Barthez and A. Sanné, a laureate of the Academy of Medicine, who was noted for his treatise on diphtheria (1877) and his graduating dissertation on tracheotomy in croup (1869).

This great work began definitely with a volume on infantile pneumonia in 1838. The first edition (1843), follows the general lines laid down by Billard and contains many case histories. In the second edition (1861), the case histories begin to disappear, and the treatise is enriched by historical studies of the different diseases and by the valuable interim clinical studies of the authors, in particular, Rilliet on tuberculous meningitis (1846), intestinal hemorrhage of the newborn (1848), sclerema (1848), essential paralysis (1851), poliomyelitis (1851),* encephalopathic albuminuria (1853), dyspepsia and apepsia (1854), dilatation of the stomach (1858) and Rilliet and Barthez on the history of typhoid fever and the anginas (1840–41), tuberculosis of the bronchial glands (1840–41), chronic hydrocephalus (1842), arachnoidal hemorrhage (1842), the history of bronchitis and bronchopneumonia (1851) and the signs of chronic pleurisy (1852–3). In the third edition (1884), sometimes called "Barthez and Sanné," the case histories have entirely disappeared, after the modern fashion, and the details of historical development of different diseases in children, with the valuable footnotes, make this edition, in the words of Ruhräh, "a perfect treasure-house of information,"† a book for the desk of all learned pediatrists. The account of poliomyelitis occurs on p. 545 of Vol. II of the second edition (1861). Much attention is paid to gastritis and "softening of the stomach" described by Jaeger (1786), which John Hunter regarded as post-mortem auto-digestion, which Trousseau defined as a "choleriform enteritis" with post-mortem gastric changes, and which the earlier American pediatrists termed cholera infantum or "summer complaint" ("cholerine" of Bourgeois).

Ernest **Bouchut** (1818–91), a Paris graduate of 1842 and physician to the Hôpital des enfants malades (1872), was a pioneer in the use of the ophthalmoscope in the diagnosis of nervous diseases (1865) and the jurisprudence of death, wrote an important book on neurasthenia (*Du nervosisme*, 1860) a good history of medicine (1864, 1873), an atlas of ophthalmoscopy and cerebroscopy (1876), treatises on diagnosis (1883), seminal vitalism (1888) and several important books on pediatrics, notably those on the diseases of children (1845, 6. ed., 1873) and the hygiene and nutrition of infants (1845, 5. ed., 1866). In 1858, he published important researches on the laws of infantile mortality, and, in 1884, a pediatric Clinique which consists of 60 clinical lectures, like those of Andral, Valleix and Trousseau. In 1858, he outlined a plan for intubation of the larynx, which met with such rebuffs from the Academy of Medicine that he abandoned it.

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* Rilliet, Gaz. Méd. de Paris, vi (1851), 3d s., pp. 681, 704.

† J. Ruhräh, "A Manual of the Diseases of Infants and Children," 3d ed., Philadelphia (1911), p. 514.

His *Manual pratique* of 1845, treats of the hygiene and nutrition of infancy, the semeiology of infantile diseases, after the manner of Billard, with sections on diseases of the mouth, abdomen, nose, larynx, chest, exanthemata and skin diseases, eyes and rickets, illustrated by clinical cases. The sixth edition (1873) is a massive volume of 1092 pages. Although Bouchut was a famous medical historian in France, his pediatric treatise contains little history, but his book on infant hygiene is illustrated with interesting pictures of nursing bottles, bathing, walking chairs, jumpers and gymnastic apparatus.

FIG. 11.—Ernest Bouchut (1818–91). (Surgeon General's Library.)

The greatest English pediatrist of his time, and perhaps the most genial practitioner of the art who ever lived, was Charles **West,** of London (1816–98). The son of a Baptist lay preacher, West was prevented by his father's religious prejudices from entering Oxford, and after a medical apprenticeship with Mr. Gray at Amersham, where he became exceedingly skilful in compounding medicines, he studied at Bonn, Paris, and Berlin, where he graduated M.D. with an illustrated dissertation on the female pelvis (1837). While waiting for practice in London, he put in a summer at the famous Rotunda Lying-in Hospital of Dublin and at Meath Hospital under Graves and Stokes (1838). In 1842, he was appointed physician to the Infirmary for Children in Waterloo Road and, in 1845, lecturer on midwifery at the Middlesex Hospital. In the meantime, he had written much and had translated Naegele on Obstetric Auscultation (1839) and Johannes Müller on the structure of cancer and tumors (1840). In 1847, he gave a course of lectures on diseases of children at Middlesex Hospital, the substance of his great work. During 1848–60, he delivered lectures on midwifery at St. Bartholomew's Hospital, which, with his published lectures on diseases of infancy and childhood (1848) and on diseases of women (1856–8), were the foundation of his fame. In 1852, West established the Children's Hospital in Great Ormond Street, where he was senior physician until 1875. What he did for this institution will be described in the section on Hospitals. Admitted to the Royal College of Physicians in 1842, he became fellow (1848), censor (1863) and senior censor (1870) and delivered the Croonian lectures on ulceration of the os uteri (1852), the Lumleian lectures on "Some Disorders of the Nervous System in Childhood" (1871) and the Harveian oration (1874). About 1878 he became a Roman Catholic. In 1880, he was driven by bad health from the London fogs to Nice, where he practised until 1885. He settled in Harley Street, where many of his old patients came back to him, but he found the doors of the London hospitals closed to him, and after some years of travel and struggle with ill health, he died at Paris on March 19, 1898, at the age of 81. West, a refined, sensitive, pietistic nature, a born orator, a master of simple flawless English, took his profession with priest-like seriousness, was sometimes in hot water with colleagues, had to leave the Children's Hospital and St. Bartholomew's, but was an ideal physician with women and children. Children stopped crying and came to him at once. Through a charming ritual, with marvellous toys, of which the drawers of his office desk were full, he had no difficulty in making the most accurate diagnosis, wrote the most palatable prescriptions and never gave a medicine which he had not previously tasted himself. In spite of the professional hazards incurred by his ideal of the physician's calling—*Benedictus qui venit in nomine Domini*—he practised his specialty in a big human way, rarely equalled and never excelled.*

FIG. 12.—Charles West (1816–98).

The pediatric writings of West include, besides the treatises mentioned, a beautiful lecture to nurses on "How to nurse sick children," first issued anonymously (1852), later under his own name (1855). This is a good example of the classical perfection and simplicity of his style, as also his "Mother's Manual of Children's Diseases" (1885). The pediatric treatise of 1848, passed through seven editions, and was translated into nearly every European language, including Arabic. The German translation of 1865 was edited by Henoch. The sixth edition is based upon nearly 200 clinical cases and 600 post-mortem examinations. The book opens with an admirable lecture on examination of the sick child, and case-taking, after which diseases of the brain and nervous system, respiratory organs, heart, digestive organs, urinary organs and fevers are handled in successive chapters. The classification is *a capite ad calcem*, as in the old Salernitan treatises. The importance of breast feeding in the prevention of infantile diarrhea and tuberculosis is emphasized. The account of infantile tuberculosis, the account of poliomyelitis (Kennedy's or morning paralysis), and the table showing the composition of different kinds of milk with the deduction that asses' milk is chemically the best for infant feeding are important points in the book, which Jacobi describes as "one of the most instructive and eloquent in medical literature."

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* For the life of West, see Brit. Med. Jour., i (1908), pp. 921–923.

American pediatric literature up to 1896 has been carefully analyzed by Samuel S. Adams.*

The outstanding items are the post-mortem sections of cholera infantum by James Stuart (1806), James Jackson (1812), William E. Horner (1829) and J. Lewis Smith (1858), Edward Miller's advocacy of cold bathing in fevers and cold clysters in tormina and tenesmus (1814), the pioneer brief for school hygiene by Edward Reynolds (1833), W. W. Gerhard's papers on smallpox (1832), measles (1833), tuberculous meningitis (1833) and pneumonia (1834) in children, Samuel Jackson's paper on cold water in malignant scarlatina (1833), John Watson's letter on surgical diseases of childhood (1853), Joseph O'Dwyer's device of intubation in diphtheritic croup (1879–86) and the pediatric treatises of "An American Matron" (1810), George Logan (1825, William P. Dewees (1825), which combats swaddling, the abuse of cradle-rocking and the chewing of infant's food by the nurse, John Eberle (1833), who follows Dewees, James Stewart (1843), D. Francis Condie (1847), J. Forsyth Meigs (1848), Charles D. Meigs (1850), J. B. Beck on infant therapeutics (1849) and the later books of Jacobi, Smith, Keating, Starr, Rotch and Holt.

It seems, in an old cant phrase "almost providential" that Meissner should have extended his fine bibliography of pediatrics up to the year 1850, for his arrangement of titles affords a clear view of the different cross-currents affecting the progress of this science at the close of an epoch. Helmholtz's essay on the Conservation of Energy (1847), Virchow's Cellular Pathology (1858) and Darwin's Origin of Species (1859) signalized the advent of a new way of looking at things, the beginnings of the more exact and scientific medicine of the laboratory and the clinic. While this tendency did not affect pediatrics appreciably before the beginning of the twentieth century, it was heralded by the rise of German influences in the works of Bednar, Gerhardt and Henoch, the forerunners of the metabolists. Up to the middle of the century, the trend of pediatrics had been determined by French influences, which were fourfold, viz., the effect of the teachings of Bichat, Cruveilhier, Laënnec, Louis and Chomel upon internal medicine; second, the cult of teaching internal medicine and pediatrics by case histories, inaugurated by Andral and Valleix; third, the example set by Billard in the classification, nomenclature, and delineation of infantile diseases; fourth, the effect of the doctrines of Broussais, which exerted a marked effect upon infantile pathology for nearly half a century. Broussais maintained that disease is merely the effect of local inflammation upon some part of the body, that specific morbid poisons are non-existent, that to label a group of symptoms with a name is merely "ontology," and that most internal disorders are the effect of gastro-enteritis. All medical Paris was for a time polarized by these theories of Broussais, an old army surgeon of Napoleon's campaigns, who had once sworn at troops as a sergeant and swung a privateersman's cutlass in the Revolution. As he approached the scriptural span of life, Broussais grew more and more tyrannical. Laënnec likened him to Paracelsus. The satirical fun-loving Parisians of the younger set—Louis, Chomel, Trousseau, Velpeau—were fain to see him as Gambetta later envisaged MacMahon: "*Il est resté parce qu'il n'a pas compris qu'il devait s'en aller.*" But through his influence infantile diarrhea, typhoid, and other intestinal disorders were regarded as symptoms of gastro-enteritis. Even after the time of Billard, indeed as late as 1845, P. Hood in his "Practical observations on the diseases most fatal to children," proposes that they be treated as resulting from "irritation" rather than inflammation, which is mere empty phrasing. The attempt at an exact classification of the disorders of infant nutrition is mainly characteristic of Bednar, Gerhardt, Henoch, and the later German school.

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* S. S. Adams, Tr. Am. Pediat. Soc., N. Y., ix (1897), pp. 5–31.

Between 1800 and 1850, Meissner lists some 150 separate treatises on pediatrics. Apart from those already named, the books of Friedrich Jahn (1803), which follow the Brunonian theory, Ludwig Formey (1811), J. Capuron (1813), J. Feiler (1814), L A Gölis (1815), J. M. Combes-Brassard (*L'ami des mères*, 1819), A. Levreton (1820), M. Veron (1821), C. T. Haden (1827), F. A. von Ammon (1827), Miles Marley (1830), F. L. Legendre (1846), James William Coley (1846) deserve mention. From Dublin came the "Observations" of Gustave Hume (1803) and the "Practical Treatise" of Richard T. Evanson and Henry Maunsell (1836), from Italy the "Compendio" of Giuseppe Maruncelli (Naples, 1808).

In the second half of the nineteenth century, the principal writers on pediatrics were mainly German.* After the death of Parrot French pediatry passed into eclipse and, in 1904, Escherich declared its glory had departed from it (Hutinel).

Alois **Bednar,** a docent at the University of Vienna, was, in the words of Jacobi, "one of the most original scientific pediatrists of Europe," an active and enlightened teacher who never attained to the professoriate. He was author of a treatise on the diseases of newborn and suckling infants, in four parts (1850–53), which was translated into Dutch, a pediatric *Lehrbuch* (1856), and a treatise on infant diet (1857). He gave the original description of Bednar's aphthæ, which had been adumbrated by Felix Würtz. His pediatric treatise is distinguished by most careful accounts of the different toxemias of infancy, which were so plentiful in the foundling asylums of his time.

Carl **Hennig** (1825–1911), of Dresden, graduated in 1848, at Leipzig, where he became director, of the Pediatric Polyclinic (1855), and, in 1863, of the Children's Hospital founded by him, and from which he issued reports (1866–82). He published treatises on pediatrics (1855, 3d ed., 1864), gynecology (1893), and obstetrics (1893), and wrote the monographs on the history of pediatrics, cephalhematoma, umbilical diseases, sclerema, diseases of the female sexual organs, and diseases of the thymus gland in the Gerhardt Handbuch (1877–93). His exact and learned pediatric treatise would have been better recognized had he attained more worldly prominence (Jacobi).

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* In selecting and arranging the pediatric writers of the modern German school, I wish to acknowledge the valuable information kindly furnished me by the late Dr. A. Jacobi, whose advice to younger men was ever generous, encouraging and sympathetic.

Alfred **Vogel** (1829–90), of Munich, and Erlangen graduate (1853), an assistant in Pfeuffer's clinic (1853–55), and later professor and director of the medical clinic at Dorpat (1866–86), was the author of clinical investigations on typhoid fever (1856, 2d ed., 1860), a new test for milk (1862), a monograph on diseases of the lips and mouth (1874), and a text-book of children's diseases (1860), which passed through twelve editions and was translated into English.

Johann Heinrich **Rehn**, a graduate of Marburg (1855), was one of the first to study epidemic jaundice in children (1869), published an atlas of the bony alterations of the chest (1875), described nodular rheumatism as an affection peculiar to the tendon-sheaths (1878), and contributed the monographs on rickets (1878) and diseases of the peritoneum (1879) to the Gerhardt *Handbuch.*

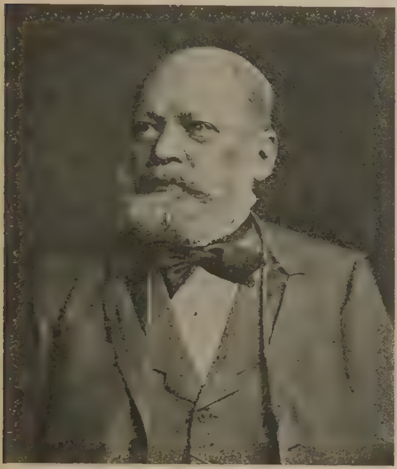

FIG. 13.—Carl Gerhardt (1833–1902).

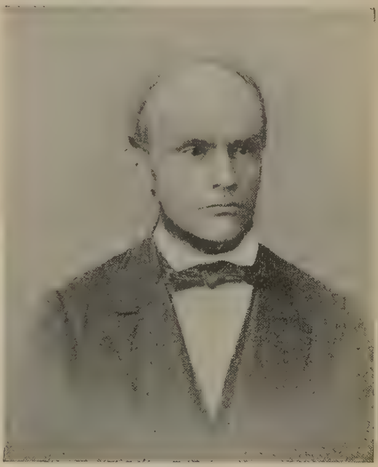

FIG. 14.—Johann Thoedor August Steffen (1825–1909). (Courtesy of Dr. A. Jacobi, New York.)

Carl **Gerhardt** (1833–1902), of Speyer, a pupil of Bamberger and Griesinger, graduated at Wurtzburg (1857), became professor and leader of the Medical Clinic at Jena (1861), and succeeded Bamberger at Wurtzburg (1872) and Frerichs at Berlin (1885). Although one of the greatest pediatrists of modern times, he disliked specialism and eschewed it. To laryngology he contributed his famous monographs on laryngeal croup (1859), paralysis of the vocal cords (1863–72), laryngeal tumors (1896), diseases of the pleura and syphilis of the larynx, and trachea (1898); to diagnosis, his treatise on auscultation and percussion (1866), to pediatrics, his *Lehrbuch* (1861, 5th ed., 1897–9) and the great *Handbuch* of 1877–96, to which the most eminent German pediatrists of his time contributed, and which, with the third edition of Rilliet and Barthez (1884), is the main storehouse of historic data about children's diseases. He also introduced the iron chloride reaction for acetonemic urine (1865). He was a master of concise expression. "Every sentence," says Jacobi, "expressed a fact, a truth." He died on July 21, 1902, in the same year with Virchow, Kussmaul, and Ziemssen.

Johann Theodor August **Steffen** (1825–1909), of Stettin, a graduate of Halle (1848), was Pfeuffer's assistant at Heidelberg (1847–48) and subsequently physician in chief at the Children's Hospital founded by him at Stettin (1853–1900). From this institution came his *Klinik der Kinderkrankheiten* (1865–89), his essays and observations on certain important children's diseases (1895), and his monographs on the pathological anatomy of childhood (1901) and malignant tumors in children (1905). To the Ziemssen *Handbuch*, he contributed the articles on whooping cough and spasm of the glottis (1876), to the Gerhardt *Handbuch* that on cerebral disease in children (1879). He was also coeditor of the *Jahrbuch für Kinderheilkunde* (1867–1900). In 1898, Steffen proposed a strong diet for infancy, the harmful effects of which were denounced by both Heubner and Czerny (1900).*

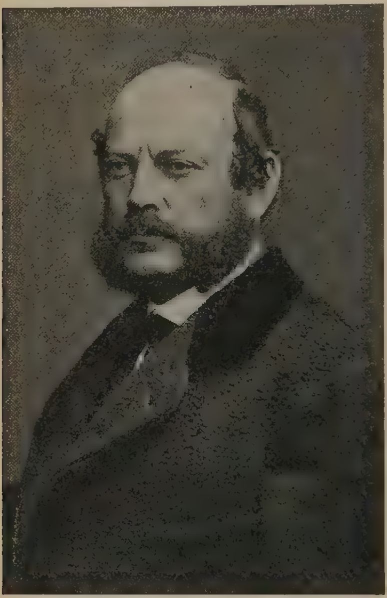

FIG. 15.—Eduard Heinrich Henoch (1820–1910). (Courtesy of Dr. George N. Acker, Washington, D. C.)

Eduard Heinrich **Henoch** (1820–1910), of Berlin, a pupil of Schönlein and Romberg (his uncle), graduated at Berlin in 1842, became professor extraordinarius (1858) and was director of the Pediatric Clinic and Polyclinic at the Charité for twenty years (1872–93) after which he retired to Meran and Dresden. He published clinical contributions from Romberg's polyclinic (1846–51), a clinic of abdominal diseases (1852–58), a series of Contributions to Pediatrics (1861–68), lectures on children's diseases (1881, 11th ed., 1903), which was translated into English (Sydenham Society, 1889), twice into Russian (1881, 1888), and French (1885). He translated George Budd's treatise on diseases of the liver (1846) and Charles West on diseases of children (1872) and was the first to describe abdominal purpura (Henoch's purpura, 1874) and dyspeptic asthma (1876). A *Festschrift* (*Pädiatrische Arbeiten*), edited by Adolf Baginsky, was published in honor of his seventieth birthday in 1890. His lectures on pediatrics are written in classic style and are described by Jacobi as "belonging to the most exquisite specimens of literature." Upon his retirement in 1893 his chair was offered to Jacobi, but being declined, was occupied by Heubner and subsequently by Adalbert Czerny.

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* Steffen, Jahrb. f. Kinderheilk., xlvi (1898), p. 332; Heubner, Jacobi Festschrift (1900), p. 290; Czerny, Jahrb. f. Kinderheilk., li (1900), p. 15. Cited by Czerny-Keller.

Otto **Soltmann** (1844–1912) of Berlin, became professor extraordinarius at Breslau (1884), where he was director of the Wilhelm Augusta Hospital (1872) and the Children's Home (1882). Called to Leipzig, he became director of the University Clinic (1894) and built the large Children's Hospital there (1898). He contributed to the Gerhardt Handbuch, published a book on the treatment of diseases of nurslings (1881, 2d ed. 1886) and wrote on infantile neurology (1875–78), gestures of sick children (1887), pavor nocturnus (1888), children's handwriting (1890), physiological peculiarities of childhood (1895), wth *Arbeiten* from his clinic (1896–98).

Fig. 16.—Adolf Baginsky (1843–1918). (Courtesy of Dr. J. H. Hess, Chicago.)

Philipp **Biedert** (1847–1916), graduated at Giessen with a dissertation on the chemical differences between human and cow's milk (1869, 2d ed., 1884), served as a volunteer medical officer in the Franco-Prussian War, became head-physician of the City Hospital at Hagenau (Alsace) and professor (1895). He was one of the original founders of the German Society of Pediatrics (1883), and inaugurated the science of artificial infant feeding. In 1879, he described "fat diarrhea" (Demme, 1874–77). He published a treatise on infant nutrition (1880, 5th ed., 1905), edited the ninth and later editions of the Vogel *Lehrbuch*, and a volume on the care of children called *Das Kind* (1906). Maintaining that cow-casein is far less digestible than casein of human milk, he introduced a series of graduated mixtures of cream, water and milk-sugar (*Rahmgemenge*) as surrogates for cow's milk, from which came the earliest preparation of preserved cream (ramogen). In 1888, Biedert signalized the difficulty of digesting casein as a prominent cause of infantile disorders.

Adolf **Baginsky** (1843–1918), of Ratibor, Silesia, a pupil of Virchow and Traube, graduated at Berlin (1866), served in the Franco-Prussian War, opened a special polyclinic for children's diseases in Berlin (1872) and became professor extraordinarius in the University (1891). In 1890, in collaboration with Virchow, he founded the Kaiser-und Kaiserin-Friedrich Kinderkrankenhaus, of which he was director. His pediatric writings include a Handbook of School-Hygiene (1876, 3d ed., 1898–1900), a series of "Practical Contributions to Pediatrics" (1881–84), a text-book of children's diseases (1882, 7th ed., 1902), monographs on diphtheria (1893–5), a treatise on infant hygiene and infant nutrition (with Paul Sommerfeld, 1906), and a large number of separate essays and popular writings. He was one of the most active and practical scientific pediatrists of modern times. In 1877, he founded, with Alois Monti, the *Central-Zeitung für Kinderheilkunde* (1877–9), which in 1880 became the *Archiv für Kinderheilkunde*, of which he was co-editor up to 1918, the volume for 1913 being a *Festschrift* in his honor. He also edited a series of *Arbeiten* from the Friedrich Children's Hospital (1891–97).

Of the Austro-Hungarian pediatrists, Ludwig **Mauthner von Mauthstein** (1806–58), of Raab, graduated at Vienna (1831) and became an army surgeon. Renouncing his military career in 1837, he took up pediatrics in Vienna. He founded an Institute for the treatment of poor sick children, which is the present St. Ann Hospital. Here Mayr, Widerhofer and Escherich made themselves famous as teachers. In 1844, Mauthner opened the first pediatric clinic. In 1850, he acquired a Children's Hospital and a professorial position. He was ennobled in 1849. He published reports from St. Ann (1851), treatises on diseases of the brain and spinal cord in children (1854) and on diet in children (1853).

Johann **Steiner** (1832–76), a graduate of Prague (1858), where he became professor extraordinarius (1866), was the author of many contributions to clinical pediatrics, and of a compendium (1872), which was translated into English by Lawson Tait (1874) and into French (1880).

The founder of the brilliant Vienna school, with its elaborated semeiotics, was Franz **Mayr** (1814–63), of Uderns, Tyrol, a Vienna graduate of 1845, who rose from bitter poverty, to be director of St. Ann and professor of pediatrics in the University. He made extended clinical studies of 594 cases of measles (1852) and congenital syphilis (with Widerhofer and others, 1862), wrote a manual on care of children (1840) and was first editor of the *Jahrbuch für Kinderheilkunde* (1857–63).

Hermann **Widerhofer** (1832–1901) graduated at Vienna, where he became professor in 1885. He wrote a monograph on diseases of the umbilicus in the newborn (1863), the articles on diseases of the bronchial glands, stomach and intestines in the Gerhardt *Handbuch* (1878–80) and was co-editor of the *Jahrbuch für Kinderheilkunde* (1863–1901). From Widerhofer and his pupils came the close delineations of the disorders of infantile nutrition, which Heubner praises. Widerhofer's classification of gastro-intestinal diseases is however, characterized by an extraordinary minuteness.

Gottfried **Ritter von Rittershain** (1820–83), of Lemberg, graduated at Prague (1844), where he was for twenty years courtroom and prison physician, became head physician to the Foundling Asylum (1865), and professor extraordinarius of pediatrics (1865–80). In 1874, he erected a special pediatric clinic attached to the Foundling Asylum. He wrote on the pathology and therapy of rickets (1863), temporary hemophilia in the newborn (1871), mental activity (*Geistesleben*, 1871), exfoliative dermatitis in infants (1878), the hygiene of childhood (1878), and during 1865–78, issued his clinical and statistical reports from the Foundling Hospital at Prague, which are famous for their wealth of interesting pediatric material. To the history of medicine he made a memorable contribution on the ancient temple-cult of incubation (1878). He founded the *Jahrbuch für Physiologie und Pathologie des ersten Kindesalters* (1868) and was co-editor of its successor, the *Oesterreichisches Jahrbuch für Pädiatrik* (1870–78). Suffering from epilepsy (the subject of his graduating thesis), he retired to Görlitz in 1880, and died of an apoplectic stroke on August 20, 1883.

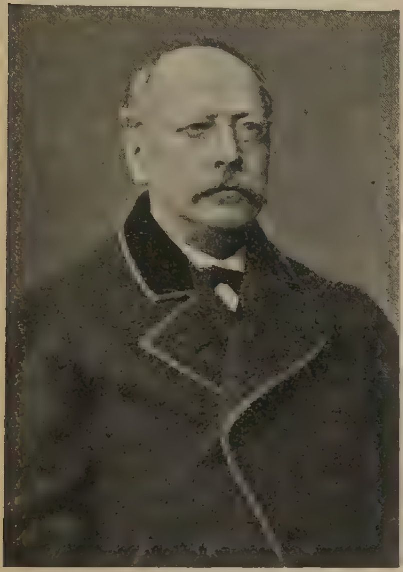

Fig. 17.—Gottfried Ritter von Rittershain (1820–1883). (Courtesy of Dr A. Jacobi, New York.)

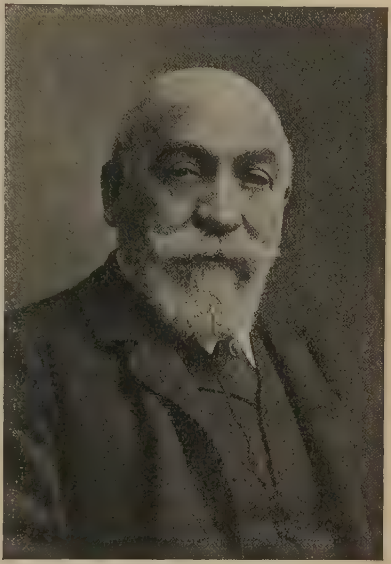

Fig. 18.—Max Kassowitz (1842–1913). (Courtesy of Dr. J. H. Hess, Chicago.)

Alois **Epstein** (1849–1918), of Kamenitz, Bohemia, graduated at Prague (1873), where he became professor and director of the Pediatric Clinic in the University (1884). He wrote on jaundice in the newborn (1880), foundling asylums (1880), duration of gastric digestion in infancy (1880–87), antiseptic measures in infant hygiene (1888), cholera infantum (1890) and disorders of infant nutrition (1899). By rigid asepsis in infant hygiene, Epstein, in fourteen years reduced the mortality in the Foundling Asylum at Prague from 30 to 5 per cent. (Heubner).

Max **Kassowitz** (1842–1913), of Pressburg, Hungary, a Vienna graduate of 1863, assisted and succeeded L. Politzer as director of the Vienna Polyclinic Institute No. I (1881) and became professor of pediatrics in the University (1891). He wrote on hereditary syphilis (1876), rickets (1881–86), lectures on children's diseases during dentition (1892), a treatise on general biology (1899) and edited a series of pediatric contributions ("Beiträge") from his Institute (1891–93). Kassowitz was the first to recommend phosphorus and cod-liver oil (*Phosphorleberthran*) in the treatment of rickets (1883), but his pathological theory of the disease has been abandoned.

Alois **Monti** (1839–1909), of Abbiategrasso, Lombardy, graduated at Vienna (1862), became Widerhofer's assistant (1862–69), and eventually professor extraordinarius at the University. He wrote the articles on epidemic cholera, diseases of the kidneys and suprarenal bodies, and hemorrhage of the spinal cord in the Gerhardt *Handbuch* (1878–84), and monographs on croup and diphtheria in children (1884), nutrition up to weaning (1897), disorders of infantile nutrition (1897–98), visceral diseases in children (1898–1903) and a series of clinical lectures on pediatrics (1897–1903). With Adolf Baginsky, he was founder and co-editor of the *Central-Zeitung für Kinderheilkunde* (1877–79) and its successor, the *Archiv für Kinderheilkunde* (1880–1909).

Ludwig **Unger** (1848–) of Marienthal, Hungary, a Vienna graduate of 1870 wrote on cortical epilepsy (1886) and diffuse insular sclerosis (1887), in children, published a text-book of pediatrics (1890, 3d ed. 1901), and translated the *Regiment* of Metlinger (1904).

Janos **Bokai** (1822–84), of Igló, Hungary, graduated at Budapest (1847), where he became chief physician to the Hospital for Poor Children (1849) and professor of pediatrics in the University. He was instrumental in the erection of a fine children's hospital of modern type at Budapest (1884). He wrote the monographs on diseases of the male organs, bladder and rectum in the Gerhardt *Handbuch* (1878), and was co-editor of the *Jahrbuch für Kinderheilkunde* (1858–84).

In Russia, Karl **Rauchfuss** (1835–1915), of Petrograd, physician and prosector to the Foundling Asylum (1858–68), director and head-physician of the Children's Hospital (Prince Peter of Oldenburg) in Petrograd (1869) the construction of which was superintended by him (1867–69), also built the St. Vladimir Children's Hospital in Moscow (1874–76) and became pediatrist to the Czar in 1876. He wrote the articles on children's hospitals, diseases of the larynx, congenital abnormalities and fetal diseases of the heart in the Gerhardt *Handbuch* (1877–82), and a number of papers on thrombosis of the pulmonary artery in infancy (1859), congenital stenosis of the aorta (1860), joint inflammation in infancy (1863), croup (1885), etc. All these papers are valuable for new data, and the historical study of children's hospitals (1877) is perhaps the best ever written. Rauchfuss practiced the most rigorous isolation of contagious cases in his wards, and was highly esteemed, both as specialist and scientific surgeon, in the Russian capital.

Nil Féodorovich **Filatoff*** (1847–1902), a native of the Penza Government, graduated at Moscow (1869) and after a course of study at Vienna and Prague, under Widerhofer, Monti, and Steiner, became privat-docent in pediatrics in the Moscow Faculty (1876) and professor in 1891. At the same time, he became director of the new Chludoff Children's Hospital, which, through his engaging lectures, he made one of the finest pediatric clinics in the world. He wrote a series of lectures on infectious diseases in children (1885–87), a highly esteemed treatise on the semeiology and diagnosis of children's diseases (1890)—both frequently translated—and a number of shorter pediatric textbooks and lecture-courses on pediatrics. In his lectures on infectious diseases (1887, II, 113), he first described as "scarlatinal rubella" the anomalous exanthem which Dukes, in 1900, described as the **"fourth disease"** (Filatoff-Dukes disease). He was the first president of the Moscow Pediatric Society (1892) and was annually reëlected until his death. In spite of his occasional brusquerie, he was universally beloved for his large, unselfish unprejudiced nature.

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* The name is usually spelled, according to German transliteration, "Filatow." The accent is thrown upon the second syllable.

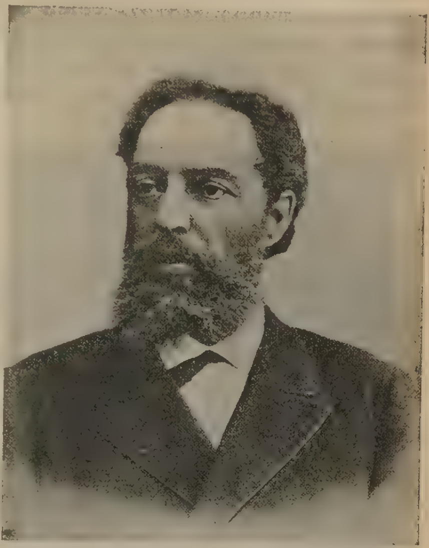

Fig. 19.—Nil Féodorovich Filatoff (1847–1902).

Dmitri Alexandrovich **Sokoloff** (1861-) has published a clinic of pleurisy in children (1906) and a remarkable collection of photographs of sick children (1914). From the laboratory of the Kaiserin Augusta Victoria Haus, Berlin, came important studies by Arvo **Yllpö**, of Helsingfors, on icterus neonatorum and congenital obstruction of the bile-ducts (1913).

In France, Armand **Trousseau** (1801–67), of Tours, the eminent clinical lecturer of the Hôtel Dieu, performed the first tracheotomy in Paris (1831), eventually averaging 25 per cent. of recoveries in 200 cases, introduced the well-known diagnostic sign in infantile tetany, described laryngeal phthisis, gastric vertigo, the cutaneous and mucous diphtherias, recreated French therapeutics and originated thoracentesis in pleurisy (1843). It is said that Trousseau put choleriform enteritis on the pediatric map. His famous *Clinique médicale de l'Hôtel Dieu* (1861) did much for the specialty of children's diseases. The lectures on scarlatina, measles, rubella, mumps, diphtheria, aphthæ, laryngismus stridulus, infantile convulsions, tetany, whooping cough, incontinence of urine, cholera infantum, lactation and dentition, syphilis in the newborn and rickets make up what is virtually a substantial pediatric treatise within the great work itself. This was the last time that important pediatric contributions were published as a subsidiary portion of internal medicine, yet never, perhaps, under more brilliant auspices.

Marie-Jules **Parrot** (1839–83) of Excideuil (Dordogne), a Paris graduate of 1857, succeeded Lorain as professor of medical history in the Paris Faculty (1876), which chair he subsequently exchanged for that of pediatrics. He described syphilitic pseudo-paralysis (Parrot's disease) in the newborn (1872), and its relation to rickets, also different diseases of the brain in infancy (1868–75). In his *Clinique* of 1875, he introduced the concept "athrepsia," a general state of malnutrition, as the deep, underlying cause of most infantile diseases, which has been latterly ridiculed by Hutinel. In 1881, Parrot, Tarnier, Fournier and others attempted infant nutrition (particularly in congenital syphilis) by direct suckling from the udders of the goat, as depicted in the art of antiquity and recommended by Raulin (1769). As shown by Marfan, the merits of the method were "possible but not probable," *i.e.*, it may bring on rickets and has otherwise no special advantage.

FIG. 20.—Jacques-Joseph Grancher (1843–1907). (Courtesy of Dr. John John S. Fulton, Baltimore, Md.)

FIG. 21.—Victor-Henri Hutinel (1849–).

Henri-Louis **Roger** (1809–91) of Paris, where he took his medical degree (1839), was physician to the Hôpital Sainte-Eugénie (1860–75), and wrote a treatise on auscultation (with J. B. P. Barth 1850), a treatise on the semeiology of infantile diseases (1864), and a series of *Recherches cliniques* on chorea, rheumatism, heart disease, syphilis and whooping cough in children (1867–83). He described the congenital interventricular communication known as "Roger's disease."

Jacques-Joseph **Grancher** (1843–1907), of Paris, famed for his graduating dissertation on the unity of phthisis (1872), wrote much on pulmonary tuberculosis (1872–90), a series of papers on isolation and medical antisepsis in the Hôpital des enfants (1889–90),* and collaborated with Comby and Marfan in a massive *Traité des maladies de l'enfance,* in five volumes (1897, 2d ed., 1904–5). At the Hôpital des enfants malades, Grancher introduced surgical asepsis in the children's wards (1889), each infectious case being "boxed" in a quadrangular wire cage, which no one was allowed to enter except in a surgical gown.

Victor-Henri **Hutinel** (1849–), of Chatillon-sur-Seine, graduated at Paris with a dissertation on disturbances of the venous circulation in children (1877), became professor of clinical pediatrics in the Paris Faculty, and succeeded Grancher at the Hôpital des enfants malades. At the Hôpital des enfants assistés, Hutinel replaced the wire screens (*grillages*) of Grancher by transparent glass screens with doors and the usual aseptic ritual of entry and egress (1894).* These isolation cubicles were widely imitated.

He wrote on diseases of the intestines (1907), introduced the excellent Elements of Infantile Semeiology by Fernandes Figueira (1903) and edited the five-volume system of pediatrics entitled *Les Maladies des Enfants* (1909). He is also co-editor of the *Archives de médecine des enfants* (1898–1922).

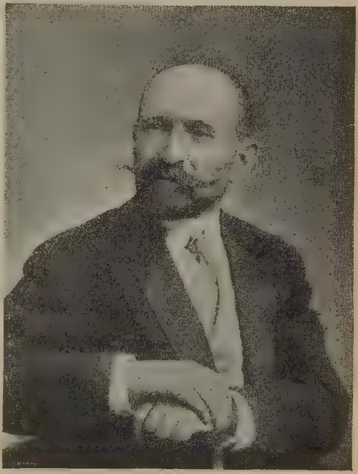
Fig. 22.—Jules Comby (1853–).

Jules **Comby** (1853–), of Pompadour (Corrèze), a Paris graduate of 1881, and chief physician to the Hôpital des enfants malades, is the author of monographs on zona (1889), rickets (1892), mumps (1893), pulsatile empyema (1895) and diathetic diseases (1901) in children, a pediatric treatise (1892, 5th ed.,1907), a pediatric formulary (1894) and pocket formulary (1901), a treatise on infantile therapeutics (1900) and a series of pediatric consultations (1910). He is editor of *La Médecine Infantile* (1894) and co-editor of the *Archives de médecine des enfants* (1898–1922) and the five-volume *Traité* (1897) mentioned above.

Gaston-Félix-Joseph **Variot** (1855–), of Demiguy (Säone-et Loire), graduated at Paris with a thesis on leucocythemia (1882), became physician to the Hôpital des enfants malades and professor of infantile surgery in the Paris Faculty and is author of treatises on the formed elements of the blood (1886), household pediatrics (1892), diphtheria and serum therapy (1898) and infant hygiene (1908, 1910).

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* Grancher, Rev. d'hyg., Paris, xi (1889), p. 204; xii (1890), p. 495.

He translated the Goodhart pediatric treatise (1895) and edited the *Journal de clinique et de thérapeutique infantiles* (1893–94). At his *goutte de lait* at Bellevue, he did much philanthropic work.

Bernard-Jean-Antonin **Marfan** (1858–), of Castelnaudary (Aude), graduated at Paris (1887) and became chief of the clinic in the Hôpital Necker and professeur agrégé (in the Paris Faculty 1892). He is the author of works on infantile eczema (1894), typhoid fever (1894) and peritonitis (1894) in children, congenital infections in the newborn (1897), infant nutrition (1899), infantile gastro-enteritis (1900), diphtheria and diseases of the air-passages (1905), diseases of the respiratory diseases, in the Bouchard system (1892), collaborated with Grancher and Comby in their pediatric system of 1897, and is editor of *Le Nourrisson* (1913–22). In 1900–1902, he demonstrated and investigated, with Charles Gillet, the oxidizing and fat-splitting ferments in milk (oxydase and lipase).*

In Great Britian, the obstetrician Fleetwood **Churchill** [1808–78], of Nottingham, England, who graduated M.D. at Edinburgh (1831) and practiced in Dublin, published a large treatise on diseases of children (1850), which was popular and was edited in America by William V. Keating.

Sir James Frederic **Goodhart** [1845–1916], of London, an Aberdeen graduate of 1873, became assistant physician (1877) and physician (1886–98) to Guy's Hospital, where he did much post-mortem work and lectured on pathology to the medical school. He was also pathological assistant to the Museum of the Royal College of Surgeons, prepared the Supplementary Catalogue (1879) and assisted Sir James Paget in preparing the new edition of the whole catalogue (1885). In 1885, he also published his Students' Guide to the Diseases of Children, which reached its tenth edition in 1913 and was translated into French. In the later English editions, Goodhart was assisted by Still, while the American editions were edited by Louis Starr. This book, the work of an expert pathologist and clinician, has been highly esteemed as confining itself to diseases peculiar to children and not attempting to cover the whole of internal medicine.

Henry **Ashby** (1845–1908), of Manchester, a medical graduate of the University of London (1878), was a forerunner of the brilliant group of English public health officers who have done so much, in recent years, for infant welfare. In 1879, he was appointed physician to the Manchester (Pendlebury) Hospital for Sick Children (168 beds), which he served for nearly thirty years. During 1880–1908, he was lecturer on pediatrics to Owens College and the University of Manchester. He did much for popular propagandism in aid of infant welfare and a pure milk supply, gave important evidence before the Interdepartmental Committee on Physical Deterioration (1904), examined the feeble-minded (1900) for the Manchester Schoolboard, and the epileptics (1915) for a Royal Commission, and established the Residential School for 65 epileptic children in Swinton Park. Its success was entirely due to his efforts. He published a useful manual of "Notes on Physiology (1878, 8th ed., 1910), popular lectures on infant feeding (1878–82), Health in the Nursery (1898), and with George Arthur **Wright,** consulting surgeon to the Royal Infirmary Manchester, a treatise on the medical and surgical diseases of children (1889, 5th ed., 1905), which was signalized by Jacobi as the first in which a surgeon and pediatrist collaborated to produce a work of unusual merit.

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* Marfan and Gillet, Monatsschr. f. Kinderheilk., i (1902–3), pp. 57–63.

Sir Thomas **Barlow** (1845–), consulting physician to the Hospital for Sick Children, London, and president of the Royal College of Physicians (1910–15), wrote the classical paper on **infantile scurvy** or "Barlow's disease" (1882),* a condition which had already been vaguely outlined, in connection with infantile rickets, by Glisson (1650) and J. O. L. Möller (1856–60). Barlow has also written on pleurisy (1877) and rheumatism (1883) in childhood, and collaborated with Goodhart and Macnamara in the Collective Investigation Committee's reports on acute rheumatism and inherited syphilis (1882).

Fig. 23.—Henry Ashby (1845–1908).

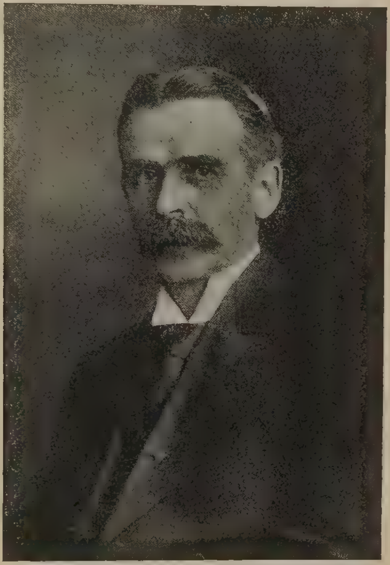

Fig. 24.—George Frederic Still (1868–)

George Frederic **Still** (1868–), professor of pediatrics in Kings College, London, and physician to the Great Ormond Street and other children's hospitals, made his mark in internal medicine by his original description of arthritis deformans in children or "Still's disease" (1896).† He wrote the treatise on rickets in Osler's Modern Medicine (1907), edited the Goodhart treatise (1905–10) and Charles West's tract on nursing (1908) and has published an admirable treatise on the "Common Disorders and Diseases of Childhood" (1909, 2d ed., 1912).

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* Barlow, Med. Chir. Tr., London, lxvi (1882–3), pp. 159–219.

† Still, Med.-Chir. Tr., London, lxxx (1896–7), pp. 47–59, 3 pl.

Sir Arthur **Newsholme,** late Medical Officer of the Local Government Board, associate editor of the *Journal of Hygiene,* and author of works of Vital Statistics (1889), the natural history and affinities of rheumatic fever (1895), epidemic diphtheria (1898), the causes of the reduction in death rate of phthisis (1906) has rendered signal service to preventive pediatrics through his five reports to the Local Government Board on infant, child and maternal mortality (1910–16), which have established the multiplex causation of infant mortality, its importance as a true index of the adult health of a community and the necessity of manifold devices to combat the evil.

Fig. 25.—Janet Lane-Claypon.

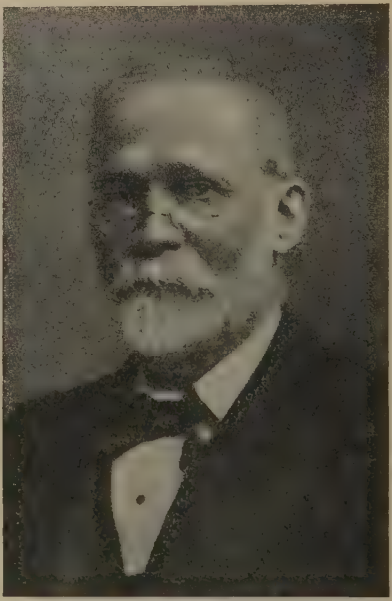

Fig. 26.—Job Lewis Smith (1827–1897).

Janet-Elizabeth **Lane-Claypon,** a graduate of the London School of Medicine for Women, and of University College, was assistant Medical Inspector of the Local Government Board (1912–16), and is perhaps the most remarkable living physician of her sex. In 1906, she performed, with Starling, one of the fundamental experiments in endocrine doctrine, showing that section of the nerves supplying the mammary gland does not inhibit lactation, and that after section of the spinal cord in the rabbit, parturition and lactation proceed as ordinarily. Her report to the Lister Institute on the status of child welfare in Europe and her investigations of milk were of basic importance. She is the author of three recent books on Milk and its Hygiene (1916), The Child Welfare and Movement (1920) and The Hygiene of Women and Children.

John **Thomson,** of Edinburgh, translated Henoch's *Vorlesungen* (1889), wrote the monographs on hemorrhage in the newborn in Allbutt's System of Medicine (1909), a useful Guide to the Clinical Examination and Treatment of Sick Children (1898), which has been translated into Russian (1801); and papers on congenital obliteration of the bile-ducts (1891–92) congenital gastric spasm (1897) and causation on congenital stridulism (1901).

David **Forsyth,** physician to the Evelina Hospital for Sick Children, London, is the author of "Children in Health and Disease," a study of child-life (1909), lectures on medical diseases for nurses (1913), a book on psychoanalysis (1913) and a fascinating history of infant feeding from Elizabethan times (1911).

Leonard **Findlay** of Glasgow (M.D., 1904) is the author of studies on the intestine as a pathway of infection for the tubercle bacillus (1913), and the etiology of rickets (1916). The lectures on Diseases of the Long Bones in Children (1894) by the late Thomas Pickering Pick (1841–1919) deserve especial mention here.

The best known American pediatrist of his time, with the single exception of Jacobi, was Job Lewis **Smith*** (1827–97), of Spafford, New York, who graduated at Yale (1849) and began the study of medicine at Buffalo Medical College (1850) under the preceptorship of Austin Flint, who made him an interne in hospital before he took his medical degree at the College of Physicians and Surgeons, New York (1853). Smith became physician to many hospitals, was clinical professor of pediatrics in Bellevue Hospital Medical College and practised uninterruptedly in New York City for nearly fifty years (1853–97). In 1869, he published his Treatise on the Diseases of Infancy and Childhood, based upon his own clinical experience and pathological findings, which passed through eight editions (1869–96), was translated into Spanish, and is still esteemed as a solid, reliable work. During 1854–96, he made some 160 contributions to medical periodicals and systems. He was a man of modest nature, and gentle, unworldly demeanor, a friend of the unfortunate, giving up a large part of his time to the poor, frequently without compensation. He took up pediatrics only after a broad experience in general practice, and once resented a slurring imputation with the warm retort "Yes, perhaps a specialist, but I trust something more." The countenance of J. Lewis Smith, the typical family doctor of the past, is expressive of a generation, less metallic, less conceited, more gentle, modest, and considerate of others, than our own. These old-fashioned American faces we shall not see again.

In the year 1853, there came to New York one who was destined to exert a profounder influence upon American pediatrics than any other physician of the present or past. This was Abraham **Jacobi** (1830–1919,) of Hartum, Westphalia, who graduated in medicine, with a Latin dissertation at Bonn (1851) and during the next two years was held in detention in German fortresses at Cologne and Minden for revolutionary activities and "lèse majesté." Escaping to England, he eventually reached Boston and commenced practice at 20 Howard Street, New York. One year after, he invented a mirror laryngoscope of his own, which, unfortunately, he did not either patent or make public before the announcement of Manuel Garcia's invention (1855); but by 1857, he was lecturing on pediatrics in the College of Physicians and Surgeons of New York, and thus, as Adams says, "pressed the button which set the pediatric clinic in motion." Three years later, he was appointed to the first special chair of diseases of children in the New York Medical College (1860–64). In 1865, he accepted the same "clinical" chair in the Medical Department of the University of New York, and in 1870, he became clinical professor of pediatrics in the Medical Department of Columbia College (1870–99). All in all, he taught pediatrics in New York for nearly half a century (1857–99). With the exception of J. Lewis Smith, he was the only American practitioner who cultivated pediatrics at this time. With the foundation of the new pediatric chair in 1860, the faculty of New York Medical College established a pediatric clinic, with extensive bedside instruction (1862–64). Thus bedside teaching in this country was first associated with pediatric teaching,* even before internal medicine. In 1858, Jacobi published his first paper on colonic intussusception in infancy, which was followed by a paper on infantile rickets (on premature closure of the fontanelles and cranial sutures) and a volume of "Contributions to Midwifery and Diseases of Women and Children" (1859) by Jacobi and Emil Noeggerath. This was followed by his initial course of lectures on Diseases of the Larynx (1859). He wrote much on diphtheria during 1860–80, and published, in succession, books on Dentition and its

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* For the life of J. Lewis Smith, see the Memorial Notices by Ellsworth Eliot, Tr. New York Acad. Med. (1896–1901), pp. 220–231, and John Strady, Tr. New York State Med. Assoc., N. Y., xiv (1897), pp. 524–538 (with bibliography).

FIG. 27.—Abraham Jacobi (1830–1919).

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* "If ever you will recall for yourself and your friends the first, the very first beginning of medical bedside instruction in America, please tell them of the small college on East 13th Street—I believe 118—which had to close its doors in 1864, a victim of the Civil War, which deprived us of all of our Southern students. That is part of your American medical history worth remembering. I was permitted to be quite active in this successful enterprise, and utilized my opportunities in preferring my pets, the young patients. My later experience will teach you that successive bedside teaching was almost exclusively pediatric. Thus pediatry was the example of giving correct medical instruction. Jacobi, Arch. Pediat., New York, xxxiv (1917), p. 10.

Derangements (1862), Infant Diet (1872, 1874,* 1878), Diphtheria† (1876, 3d ed., 1903), the Intestinal Diseases of Infancy and Childhood (1887), Diseases of the Thymus Gland (1889), Therapeutics of Infancy and Childhood (1896, 2d ed., 1903) and a series of clinical lectures (stenographed, 1893). With Emil Noeggerath, he was the founder and editor of the *American Journal of Obstetrics* (1868–71). To the Gerhardt *Handbuch*, he contributed monographs on the care and hygiene of children (1876, 2d ed., 1882), diphtheria (1877), and dysentery (1877). The first of these, written with force, fire and a vast amount of fine sarcasm, is of unusual historical and practical value, by reason of its accurate bibliographies (four years before the appearance of the Index Catalogue), its lively arraignment of the various artificial foods, its wholesale denunciation of existing shams and abuses, and its rare common sense. The treatise on infantile therapeutics (1896) is, in effect, a treatise on pediatrics, summarizing the author's views and revealing his wide knowledge of the literature. Jacobi's teaching in regard to infant nutrition is simple: mother's milk first and foremost, raw unpasteurized cow's milk never, but corrected by cereal decoctions and salt; the use of cane sugar in place of milk sugar, which is different in human and cow's milk and frequently adulterated. A high percentage of fat is adjudged harmful, and a monotonous diet is especially to be avoided, as leading to scurvy, rickets and other deficiency diseases. One by one, the practical bedside physician and the laboratory specialist alike have come around to the substance of these views.

During sixty years of active practice, Jacobi had written a vast number of clinical papers, essays and public discourses, which are remarkable for the subtle wisdom of long experience, wide learning which is never obtruded, and delicate humor. These have been published as Collectanea Jacobi in eight volumes (1909),‡ five of which are devoted to pediatrics. Among the more important papers are those on laryngeal catarrh (1859) and laryngismus stridulus (1869), craniotabes (1871), masturbation and hysteria in infants (1875), rickets (1885), acute catarrhal and pseudo-membranous laryngitis (1885), stomatitis neurotica chronica (1894), the muscles of rachitic infants (1894), nephritis of the newborn (1896), milk sugar in infant feeding (1901) and the memorable discourse "Non nocere" (1894). To the history of pediatrics, Jacobi has contributed several important papers, notably his history of American pediatrics before 1800 (1902), his St. Louis address (1904), pediatrics in the United States (*Baginsky-Festschrift*, 1913), the history of cerebrospinal meningitis in America (1905) and the history of pediatrics in New York City (1917); to the history of medicine, his memorial notices of Ernst Krackowizer (1875), Virchow (1881–1901), Austin Flint (1886), Carl Gerhardt (1902), valuable histories of nursing (1883), therapeutics (1905), medical libraries (1906), American medicine (1900), German medical teaching (1901) and his letters on the condition of American medicine (1909).

The later writings of Jacobi are characterized by a vein of irony of the most delicate and elusive type. There is often a quaint surprise in every sentence. The mirthful goddess, *quam Jocus circumvolat,* is seldom absent from his pages, and this omnipresent sense of humor has endeared him particularly to Americans. A banquet, with presentation of a loving-cup and the publication of a *Festschrift,* was held, in honor of his seventieth birthday, on May 6, 1900. As our first teacher and professor of pediatrics, as the founder of bedside instruction in this country, as the founder of the pediatric sections of the American Medical Association and the New York Academy of Medicine, as the first president of the American Pediatric Society, he became through years of dignified labor and distinguished honor, the leader and the Nestor of his profession in the United States. He could have had Henoch's chair when Henoch died, but declined it to remain, in his own phrase, "a bridge between European and American pediatrics." A valued friend of Billings, it was Jacobi who secured the Congressional appropriations for printing the Index Catalogue. In advanced age, he remained ever true to the ideals of his fiery youth. Not a line in his writings that does not reveal the man who values the truth above all things, who cares more for the truth than for himself; not a public utterance but is informed with the highest type of civic and moral courage. And it was under the guidance of a man of this inherent *noblesse* of mind and character that American pediatrics has prospered to its present fair estate.

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* Revised, enlarged and adapted to popular use by Mary Putnam Jacobi.
† Translated into Italian by Vincenzo Meyer, Naples (1884).
‡ Edited by William J. Robinson, New York (1909).

Intubation of the larynx became a permanent rational procedure in pediatrics through the labors of Joseph **O'Dwyer** (1841–98), of Cleveland, Ohio, who came to New York in 1864, graduated in medicine at the College of Physicians and Surgeons (1866), served as interne in the Charity Hospital, began practice in 1868, became connected with the New York Foundling Asylum (1873), the Willard Parker, St. Vincent's and the Foundling Hospitals, and was president of the American Pediatric Society (1880). In 1880, he began to think about the possibilities of intubation, which had been neglected after the rebuffs encountered by Bouchut's idea of *tubage* (1858). In 1885, he began publishing reports of intubation in croup and chronic laryngeal stenosis, and by 1887, his claims, based upon records of hundreds of well authenticated cases, were recognized by the Medical Society of New York (State) and the New York Academy of Medicine (Jacobi presiding). Prior to this time, tracheotomy had been the procedure in laryngeal obstruction, in the practice of Ernst Krackowizer, Jacobi, Roth, Voss and others. During 1860–87, Jacobi performed tracheotomy over 700 times and assisted in more than 2000 cases. "After 1887," he says, "I rarely, ever operated, and my friends stopped tracheotomy when O'Dwyer taught us all intubation."* O'Dwyer's work was taken up with enthusiasm by Hutinel (Paris), Bokai (Budapest), Concetti (Rome) and Rauchfuss (Petrograd). He himself taught intubation with success in the New York schools. His obstetric practice was large, covering over 3000 confinements, but the death of his wife and other worries connected with over-work, insomnia from night-calls, and captious criticisms of his invention, finally broke down his health, and he died from thrombosis of the cerebellar arteries with secondary meningitis on January 7, 1898. His temperament was of the retiring, diffident kind which endures great internal suffering from senseless criticism and blundering opposition. "Whenever the records of diphtheria will be written up," says Jacobi, "there will be four names at the head of those who deserve the places of honor, Bretonneau, Trousseau, Behring and O'Dwyer."*

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* Jacobi, Arch. Pediat., New York, xxxiv (1917), pp. 5–6. For a full history of O'Dwyer's work, see W. P. Northrup, Med. Rec., New York, lxv (1904), pp. 561–564.

Another pioneer in pediatrics as a specialty, detached from internal medicine, is William Perry **Northrup** (1851–), of Peterboro, N. Y., who graduated M.D. at the College of Physicians and Surgeons, New York, 1878, and became professor of pediatrics in University and Bellevue Hospital Medical College (1896). He performed the largest number of infantile autopsies in his period. He edited the American edition of Ashby and Wright (1893) and has written on emphysema and pulmonary abscess after whooping cough (1883), pneumonia (1889–97), sclerema (1890), infantile scurvy (1890–95) and on the open air treatment of pneumonia by means of roof wards and roof gardens over private houses, of which he has been a prominent advocate.

Fig. 28.—Joseph P. O'Dwyer (1841–1898).

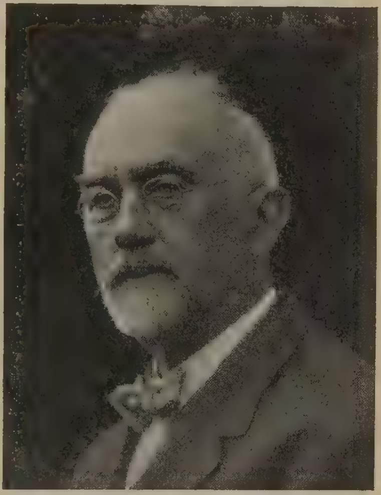

Fig. 29.—William Perry Northrup (1851–).

Samuel Shugert **Adams** (1853–), of Washington, D. C., graduated in medicine at the University of Georgetown (1879), where he has been a professor of medicine and pediatrics since 1898. He has been a prominent pioneer in his specialty and is the leading pediatrician in the national capital. He has written on strabismus convergens after diphtheria (1884), sudden death in diphtheria (1884), dentition (1889), typhoid in infancy (1895), temporary insanity following typhoid

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* Jacobi, Pediatrics, New York & London, v (1898), p. 96, 147.

(1896), and other subjects. His presidential address before the American Pediatric Society (1897), of which he was secretary for 25 years (1891–1916), is a breezy and discriminating review of American pediatric literature between 1789 and 1897, a most valuable and readable historical summary.

John M. **Keating** (1852–93), of Philadelphia, a graduate of the University of Pennsylvania (1873), and practitioner of pediatrics and gynecology, was the author of "A Mother's Guide" (1881), Diseases of the Heart and Circulation in Infancy and Adolescence (with W. A. Edwards, 1888), Mother and Child (with E. P. Davis, 1893), and in 1890–91 published a Cyclopedia of the Diseases of Children by many authors, which was the earliest coöperative American work of the kind, and did much to stimulate interest in this specialty.

FIG. 30.—Samuel Shugert Adams (1853–).

FIG. 31.—Louis Starr (1849–).

Louis **Starr** (1849–), of Philadelphia, a graduate of the University of Pennsylvania (1871), where he became clinical professor of pediatrics (1884–90), is the author of works on the digestive disorders, of infancy and childhood (1886, 3d ed., 1901), the Hygiene of the Nursery (1888, 8th ed., 1913), Diets for Infants and Children (1896), edited the American editions of Goodhart's treatise (1885, 1889), and in 1895, edited an American Text-book of the Diseases of Children by various authors (2d ed., 1899). He has also edited the department of diseases of children in the American Year-book of Medicine and Surgery.

John Price **Crozer Griffith** (1856–), of Philadelphia, a graduate of the University of Pennsylvania (1881) where he has been clinical professor (1891) and professor (1913) of pediatrics, is the author of The Care of the Baby (1895, 6th ed., 1915), a treatise on Diseases of Infants and Children (2 v., 1919) and a large number of contributions on clinical pediatrics.

Benjamin Knox **Rachford** (1857–), of Alexandria, Kentucky, a graduate of the Medical College of Ohio, Cincinnati (1882), where he is now professor of pediatrics (1901), is the author of a treatise on the Neurotic Disorders of Childhood (1905), a treatise on Diseases of Children (1912) and a number of minor contributions.

Henry **Koplik** (1858–), of New York, a graduate of the College of Physicians and Surgeons (1881), and attending pediatrist to Mount Sinai and other hospitals, discovered the spots diagnostic of measles (1898), established the first milk depot in the United States and is the author of a treatise on the Diseases of Infancy and Childhood (1902, 3d ed., 1912) and numerous clinical papers.

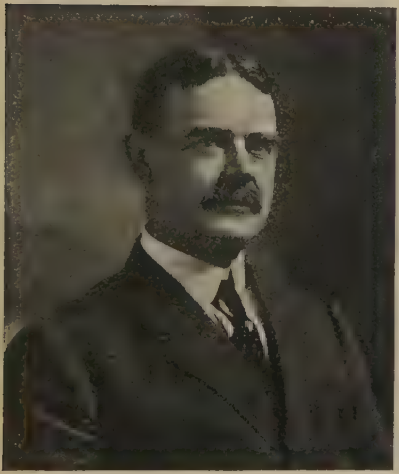

FIG. 32.—Benjamin Knox Rachford (1857–).

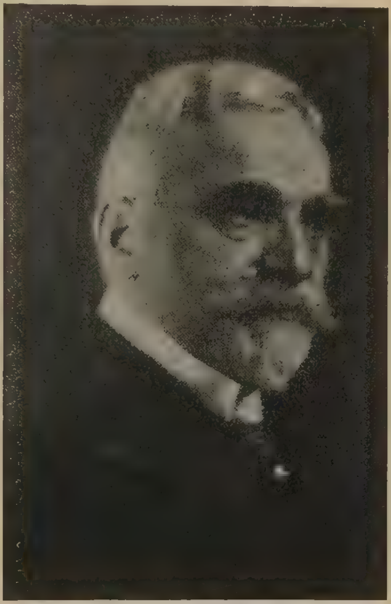

FIG. 33.—Henry Koplik.

Bernard **Sachs** (1858–), of Baltimore, Md., a graduate of Harvard (1878) and Strassburg (1882), neurologist to Bellevue and Mount Sinai Hospitals, described amaurotic family idiocy (1887–96), the ocular appearances of which had been noted by Warren Tay in 1880 (Tay-Sachs disease) and is the author of the first American treatise on the nervous diseases of children (1895).

Rowland Godfrey **Freeman** (1859–), of New York, a graduate of the College of Physicians and Surgeons (1886) and professor of pediatrics in the University and Bellevue Hospital Medical School, has written much on the sterilization of milk (1892–96) and clinical subjects, and a pediatric treatise (1917).

Charles Gilmore **Kerley** (1863–), of Red Hook, N. Y., a graduate of University Medical College of New York (1888), lecturer on Diseases of Children (1897–1903) and professor (1903) at the New

York Polyclinic Medical School, is the author of Short Talks with Young Mothers (1902), a practical and helpful book on the Treatment of Diseases of Children (1907) and a Practice of Pediatrics (1914).

Linnæus Edford **LaFetra** (1868–   ) of New York, associate in pediatrics in Columbia University and chief of the pediatric department of Bellevue Hospital assisted Henry L. K. **Shaw** (1873–   ) in editing the sumptuous translation of Pfaundler and Schlossmann's Diseases of Children (1908, 1912), and has made numerous contributions to clinical pediatrics.

Hermann Bernard **Sheffield** (1871–   ), of New York, is the author of a pediatric treatise (1911), 3d ed., 1916), the Baby's Record of Health (1913), the Backward Baby (1915) and translated E. Graetzer's Practical Pediatrics (1905). Other American text books have been written by John Madison Taylor (1855–   ) and William H. Wells, of Philadelphia (1898, Italian translation, 1903) and Charles Hunter Dunn (1875–   ), of Boston (1917).

FIG. 34.—Linnæus Edford La Fetra (1868–   ).

In Canada, Alexander **Blackader** (1847–   ), professor of pharmacology, therapeutics and pediatrics in McGill University, Montreal, has made several contributions to clinical pediatrics.

Apart from the pediatric treatises already recorded, we may mention those of Eustache Smith (1868), E. Ellis (1869), C. H. Goodwin (1883), Angel Money (1884), James Carmichael (1892) and George M. Tuttle (1899) in England; Jules Beclard (1852), Joachim Giraldés (1869), D'Espine and Pacot (1877), C. L. Cadet de Gassicourt (1880–84) and Pierre Nobécourt (1907) in France; G. A. Braun (1862), A. Stössel (1875), A. von Hüttenbrenner (1876), E. Graetzer (1891) in Germany; Andrea Pasquali (1873–6), and E. Copasso (1892) in Italy; Francisco Criado y Aguilar (1884) in Spain; I. V. Troitzy (1892–3) in Russia; and S. Miwa (1915) in Japan.

Of **original descriptions of disease,** may be mentioned those of bronchitis by Charles Badham (1808) appendicitis by James Parkinson (1812) and Louyer-Villermay (1824), laryngismus stridulus by John Clarke (1815), achondroplasia by M. H. Romberg (1817), hay fever by John Bostock (1819), asthma thymicum and thymus death by Kopp (1830), A. Friedleben (1858) and A. Paltauf (1889), osteopsathyrosis by J. Lobstein (1833), exophthalmic goitre by C. A. Basedow (1840), pituitary obesity by B. Mohr (1840), acute fatty degeneration in the newborn by Ludwig von Buhl (1861–64), adenoid vegetations by Hans Wilhelm Meyer (1868), syphilitic pseudo-paralysis of infants by M. J. Parrot (1872), infantile purpura by E. Henoch (1872), "fat-diarrhea" by Demme (1874–77) and Biedert (1879), mastoiditis by F. Bezold (1877), cyanotic hemoglobinuric jaundice by Franz von Winckel (1879), splenic anemia by G. Banti (1882), infantile scurvy by Sir Thomas Barlow (1882), periodic vomiting by Samuel Gee (1882) and Ernst von Leyden (1882), megacolon by H. Hirschsprung (1887), pseudo-rachitic osteoporosis by S. Miwa and Stoeltzner (1898), fourth disease by N. F. Filatoff (1887) and C. Dukes (1900).

Of the many **diagnostic and therapeutic devices** now employed in pediatrics, it is only necessary to mention Laennec's stethoscope (1819), thoracentesis, perfected by Trousseau (1843), H. I. Bowditch (1852), Dieulafoy (1869–72) and Estländer (1879), ether anesthesia (1846–47), Helmholtz's ophthalmoscope (1851), Manuel Garcia's laryngoscope (1855), the methods of treating asphyxia neonatorum of H. A. Pagenstecher (insufflation, 1856) and B. S. Schultze (swinging, 1871), the hypodermic syringe of C. G. Pravaz (1851–53), the developments in surgery of the mastoid and middle ear by Schwartze and Eysel (1873), Zaufal (1884), Küster (1889) and Stacke (1890–97), Koch's tubercle bacillus (1881) and tuberculin (1890), Ehrlich's diazo-reaction for acetone (1882), diphtheria antitoxin (Roux and von Behring 1890–93), the Röntgen rays (1893), H. Quincke's lumbar puncture (1895) and Gaertner's tonometer (1899).

Of treatises on **nervous diseases in children,** perhaps the earliest was L. W. Mauthner's Diseases of the Brain and the Spinal Cord (1844). A number of monographs on special subjects preceded and followed this, but apart from the Lumelian lectures of Charles West (1871), perhaps the earliest systematic treatises of importance were those of C. Pavone (Milan, 1892), B. Sachs (1895), B. K. Rachford (1905), M. Thiemich and J. Zappert (1910) and G. Peritz (1912).

Of **original descriptions of nervous diseases,** those of cerebro-spinal meningitis by Gaspard Vieusseux (1805), tetany by John Clarke (1815), S. L. Steinheim (1830), and J. B. K. Dance (1832), softening of the brain by Rostan (1820), poliomyelitis by M. Underwood (1786), John Badham (1835), Jacob Heine (1840) and Duchenne of Boulogne (1865), with the subsequent work of O. Medin (1890), Simon Flexner (1910–16), Peabody, Draper, Dochez and the report of the Swedish Medical Institute (1912), the various forms of progressive muscular atrophy by Duchenne and Aran (1847–68), Charcot and Joffry (1869), Charcot and Marie (1886), Erb (1884–91), Guido Werdnig (1890–94) and Johann Hoffmann (1894), congenital spastic paraplegia by William John Little (1861), hereditary ataxia by Nikolaus Friedreich (1863–76), amaurotic family idiocy by Bernard Sachs (1887), hereditary cerebellar ataxia by Pierre Marie (1893), progressive interstitial hypertrophic neuritis by Jules Déjerine and Jules Sottas (1893) called erythema infectiosum by Salomon Stricker (1899) and amyotonia congenita by Hermann Opepnheim (1900) may be noted.

Among the many writings on **infantile psychology** are a history of the development of the infant mind and morale up to the fourth month by R. B. (*Jour. Nat. Philos.*, 1806), the investigations of J. E. Löbisch (1851), and Adolf Kussmaul on the psychic life of the newborn child (1859), Ritter von Rittershain's *Geistesleben* (1871), Charles Darwin's Biography of an Infant (1877), Wilhelm Preyer's *Die Seele des Kindes* (1882, 8th ed., 1912), the books of J. W. Ballantyne (1890), Millicent W. Shinn (1893–1907), Biography of a Baby (1900), J. Mark Baldwin (1896), Kathleen C. Moore (1896), Maurice de Fleury (1899), Clifford G. Grulee (1915), Karl Groos on games (1899) and the psychic life of the child (1903), Albert Moll on the sexual life of the child (1899), the essays of Sigmund Freud on the same theme, and the studies of G. Stanley Hall (1880–1914).

The earlier writers on the education of children were Oribasius, Erasmus (1516, 1529) and John Locke.

Other works relating to the subject of **child-study** are the anthropometric investigations of H. P. Bowditch (1879–91), W. T. Porter (1892–3), Francis Warner (1888–1917), Arthur MacDonald (1899), Franz Boas and others, H. Ploss's *Das Kind* (1877), Timothy Dwight's *Frozen Sections of a Child* (1881), C. H. Stratz's album "*Die Körper das Kindes*" (1903), the books of A. F. Chamberlain (1896, 1900) W. M. Feldman on the Jewish Child (1917) and on ante-natal and post-natal child physiology (1920), Oscar Chrisman's The Historical Child (1920) and the literature of pedagogics.

Of treatises on **infantile surgery** and the surgical diseases of childhood, aside from two small publications on surgical diseases of the newborn by C. J. Oehme (1773) and F. Zehler (1830), the earliest of importance was that of John Cooper Forster (1860) of Guy's Hospital, which was followed by those of P. Guersant (1864–7), Timothy Holmes (1868), Joachim Giraldès (1869), Cesare Fumagalli (1875), L. A. de Saint-Germain (1884), Edmund Owen (1885), José Ribeira y

Sans (1887), Ferdinand Karewski (1894), D'Arcy Power (1895), Piechaud and Denuce (1900), Sebastian Recasens y Girol (1901), Auguste Broca (1902, 1911, 1914), Samuel W. Kelley (1909), D. G. Gorokoff (1910), William F. Campbell and L. Kerr (1912) and Louis Ombrédanne (1912). The work of Harvey Cushing (1905) and others on intracranial surgery in the newborn deserves mention here.

The history of **infantile orthopedics** is co-existent with the history of orthopedics itself. The earlier landmarks are the treatise περί ἄρϑρον of Hippocrates, the use of *redressement forcé* (Calot, 1896) by Hippocrates and Avicenna, the Children's Book of Felix Würtz (1598), the treatise of J. C. G. Jörg (1816), the writings of Underwood, Charles Badham, Rilliet and Barthez on poliomyelitis, the work of Jean-André **Venel** at Orbe (1780–91), of the elder Graefe, Dieffenbach, Stromeyer and Gustav Simon in plastic surgery and the work of the **Heine family.** The founder of this famous group of surgical mechanicians and orthopedists was Johann Georg Heine (1770–1838), of Lauterbach (Württemberg), who became surgical instrument maker and bandagist to the University of Wurtzburg in 1802. Being in friendly touch with the elder Langenbeck and other prominent German surgeons of his time, he soon learned the essentials of anatomy and the mechanical side of surgery, invented many important appliances, published several extensive catalogues of his business output, erected the Caroline Institute of Orthopedics (1816) and became orthopedist and assessor to the Medical Faculty of the University. His son Joseph von Heine (1803–77), became a well-known physician, and his nephew Bernhard Heine (1800–46), continued the business, invented the osteotome (1830), did experimental surgery on dogs, for which he won two Monthyon prizes (1835, 1838), and became professor of experimental physiology in the Wurtzburg High School. The other nephew, **Jacob von Heine** (1880–79), of Lauterbach, graduated in medicine at Wurtzburg (1829), founded on orthopedic institute at Canstatt (1829), where he made a great reputation, particularly by his classic monograph on infantile paralysis or **poliomyelitis** (1840, 2d ed., 1860), illustrated with interesting plates, and that on spontaneous and congenital dislocations (1842). It was Heine's monograph which first drew modern attention to poliomyelitis. He died, covered with honors, on November 12, 1879. In the later period, Louis Albert Sayre (1820–1900), of New Jersey, introduced jacket suspension in Pott's disease (1877); Albert Hoffa (1859–1907), at Wurtzburg, introduced a well-known operation for congenital dislocations of the hip joint (1890), and Adolf **Lorenz** (1854–), of Vienna, professor of surgery in the University, made a great reputation in Europe and America by his bloodless method of reducing congenital dislocations of the hip-joint by forcible manipulation (1895). The work of Robert Jones in Liverpool, of Royal Whitman in New York, of Abbott, Bradford, Lovett, Osgood, Codman, Goldthwait and the other orthopedists of the New England school belongs to recent surgery.

Fig. 35.—Adolf Lorenz (1854–). (Courtesy of Dr. J. H. Hess, Chicago.)

School Hygiene and Pedagogics.—In the eighteenth century, some attention was paid to the untoward effect of close mental work and sedentary occupations upon the health of the individual. At the beginning of the century, Ramazzini published his treatise on occupational diseases (1700), and later Tissot (1769), Ackermann (1771) and others wrote on the hygiene of literary men. In 1777–88, Johan Peter Frank published the first systematic treatise on public hygiene, in four volumes. The chapter on school hygiene shows the influence of Rousseau. With the single exception of school-lunches, every physical need of the school-going child is considered, and the sentences upon the correct adjustment of light, the effect of the height of benches and the slant of desks upon the eyes and the spine of the pupils, are entirely modern in spirit. After the time of Frank, there is long silence in the records, until, in 1833,* Dr. Edward Reynolds, of Massachusetts, filed a brief for a better understanding of the hygiene of young students by parents and teachers, in particular, the effects of crowded rooms, overstudy at the expense of sleep, unhygienic posture and improper diet. Three years later, C. J. Lorinser published an essay on "The Protection of Health in Schools" (1836),† which deals almost entirely with the crowded courses and the consequent overtaxing of students in the gymnasia, but emphasizes the danger of tuberculosis. This essay excited great interest, was reprinted in 1861, and was the starting point of the German propagandism. In 1842, gymnastic instruction became obligatory in Prussia. In 1862, Max von Pettenkofer published his investigations of the faulty ventilation of schoolrooms and its effects upon the pupils. Sir Henry Acland published a report on the sanitary conditions of the Cowley Industrial School in 1863. In 1865 appeared the papers of Fahrner‡ and Parow§ upon the bad effects of faultily constructed school-desks. Fahrner's work soon attracted the attention of Hermann Cohn, who was, in a very real sense, the founder of hygienic inspection of school-children.

Hermann Ludwig **Cohn** (1838–1906), of Breslau, studied physics and chemistry under Bunsen, Kirchhoff and Helmholtz, taking his doctor's degree in philosophy at Breslau (1860) and in medicine at Berlin (1863), where he was a pupil of Graefe. In 1866, he began to practice ophthalmology at Breslau, where he opened a private eye-clinic, and eventually became professor extraordinarius in the University (1873). His practice gave him an experience of some 20,000 refraction cases. In 1866, he published an investigation of myopia from defective lighting and faulty benches in 7658 school-children. In the following year came his famous monograph on the examination of the eyes of 10,060 school-children for visual defects from unhygienic conditions (1867). He found but little myopia in the village schools, five times as many myopes in the elementary schools of cities, 15 times as many in the Realschule and 20 times as many in the gymnasia. In this field, Cohn had been preceded by James Ware, who in 1812, examined the eyes of 1300 boy cadets in the Military School at Chelsea (England), by a government investigation of myopia in the school-children of the Grand-Duchy of Baden (*circa* 1840), by Szokalki's investigations of school-children in Paris (1848), by Jäger in Vienna (1861) and by Rüte in Leipzig (1865). Although Cohn drew from his figures the erroneous conclusion that the degree of visual defect is a mathematical function of the number of years of school-life, instead of the individual age as affected by heredity (Fulton)* and although the preponderance of male myopes in his statistics is easily explained, the real importance of his research lies in his insistence upon the effect of bad lighting, faulty desks and benches, and poorly printed books upon the engorgement of the eye with blood through bending and the increased intraocular pressure and extension of the eye in the vertical plane through reading at close range. This memoir was epochal as awakening the medical public, and as being the starting point of the innumerable school-inspections of various kinds which have since been made. It led to the foundation of the Society for the Prevention of Blindness (1880), which offered a prize of £80 for the best book on the subject (1882), won by Ernst Fuchs (1885).

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* Reynolds, On the Importance of a Knowledge of the Principles of Physiology to Parents and Teachers, Boston (1833).

† Lorinser, Zum Schutz der Gesundheit in den Schulen, Med. Ztg. Berlin, I, (1836), pp. 1–4.

‡ Fahrner, "Das Kind und der Schultisch." Zürich (1865).

§ Parow, Ueber die Nothwendigkeit einer Reform der Schultische, Berlin Schul.-Ztg. (1865).

Cohn meanwhile continued his propagandism along the broadest lines. In 1867–73 he took up the hygiene of schoolhouses, desks and benches, in 1878 the investigation of color-blindness, in 1880 the printing in schoolbooks, in 1882–98 the problem of medical inspection of school-children, in 1883–1902 the lighting of schoolrooms, as tested by the Weber photometer, in 1894 the color of window curtains; in 1896, he made a collective investigation of infantile conjunctivitis in the Germanic countries, and in 1903–4 he introduced regular inspection of the eyes of school children. In 1894, he published his paper on masturbation in children and in 1904, his brief for sexual instruction of the child. His monograph on the hygiene of the eye in school children (1883) became a *Lehrbuch* in 1892. Perhaps the culmination of his work was his examination of the vision of 50,000 Breslau school children (1899), in which it was shown that 85 per cent. had supernormal vision but with a continual increase in visual defect as they mounted from class to class. In this examination, Cohn used his own hook-shaped test-types, instead of letters, which were more readily guessed by the pupils. He lived to see the first Congress of School Hygiene (Nuremberg, 1904).

Cohn was a man of jovial, good-natured appearance, a true philanthropist who cheerfully taught all his life as an unpaid extraordinarius, and spent 50,000 marks upon the upkeep of his private clinic, at which 58,481 patients were treated (1866–94), of whom 39,362 (67 per cent.) were charity cases.†

In 1869, Rudolf **Virchow** published his well-known report on school-hygiene,‡ which supported Cohn in his views about myopia and dealt successively with the effects of cerebral congestion (headache, epistaxis, school children's goitre), spinal curvature, phthisis, digestive and sexual disorders, contagious diseases, wounds and injuries, ventilation, lighting, posture, exercise, mental overwork, corporal punishment, drinking water, etc.

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* I am indebted to Dr. John S. Fulton, Secretary of the State Board of Health of Maryland, for this information.

† For a spirited account of Cohn's life and work, with a full bibliography of his writings, see F. Erismann, Ztschr. f. Schulgsndhtspflg., Hamburg & Leipzig, xix (1906), pp. 829–880.

‡ R. Virchow, Ueber gewisse die Gesundheit benachtheiligende Einflüsse der Schulen," Berlin (1869).

Sir Edwin Chadwick wrote "On Schools as Centres of Children's Epidemics" (1871), and the "Sanitary Principles of School Construction" (1871). Baginsky published his Handbook of School Hygiene in 1879. After this time, the subject became *à la mode.* At the fourth International Congress of Hygiene (Geneva, 1882), the question of medical inspection of schools and school-children by trained physicians (*Schularztfrage*) was introduced and was much debated through the next twenty years. In course of time, medical as well as special inspection of the eyes, ears, nose, throat and teeth became established, anthropometric and psychophysical measurements were made, and the hygiene of the model school-house, its furniture, lighting and appointments, was carefully studied. **School-lunches,** for children, inaugurated by **Count Rumford** at Munich (1792), revived in the military *Caisse d'écoles* at Paris (1849) and by **Victor Hugo** at Guernsey (1866), were established by law in France as *cantines scolaires* (1882); while in Germany, the movement, started at Munich in 1876, had extended to half the cities in the empire by 1909. School-lunches were introduced in England in 1902 and in New York City on November 23, 1898. **Dental clinics** were started at Strassburg and Darmstadt in 1902. In, 1915, there were 120 in Germany. A Congress of School Hygiene and Physiological Pedagogics was held at Paris on November 1–2, 1903. The first International Congress of School Hygiene was held at Nuremberg on April 4–9, 1904, the second at London, 1907. As part of school hygiene, the subject of mentally deficient or "unusual" children soon began to loom large. Feeble-minded and half-witted children were roughly handled in the past. At Dessau, Martin Luther opined that an idiot child was possessed by the devil and thought drowning none too good for it. In 1801–7, J. E. M. **Itard** published his reports on the wild boy of the forest of Aveyron (*le sauvage de l'Aveyron*) which was reprinted by Bourneville in 1894. Goggenmos founded a training school for cretins at Salzburg, which died out in 1835. Sometime after, **J. Guggenbühl** (1816–63) founded a similar institution upon the Abendberg, near Interlaken, based upon the idea that the sunshine of the Alpine heights was good for cretins.

Numerous reports were published, but an unfavorable investigation by the Swiss government (1888) closed Guggenbühl's institution and he died in obscurity. In 1837, Edouard **Seguin** (1812–80), of Clamecy (Nièvre), a pupil of Itard, began to treat an idiot boy of Paris and published his results in 1839. In the meantime, G.-M.-A. Ferrus and Felix Voisin had started schools for idiots at Bicêtre, to which, in 1842, Seguin was appointed to carry out his method. This method is set forth in Seguin's publications on the education of infants (1843), on graded images for the use of backward children (1843) and his treatise on the moral treatment, hygiene and education of idiots (1846). In consequence of the revolution of 1848, Seguin emigrated to the United States, where he wrote the pioneer treatises on clinical thermometry (1871–76) and continued his pedagogic work on idiocy, in which he was a forerunner of Maria **Montessori**. Her lectures on the education of backward children led to the foundation of the Scuola ortofrenica at Rome, of which she was directress (1898–1900). Her method is set forth in her *Anthropologia pedagogica* (1911). The education of the blind deaf-mute Laura Bridgman (1829–89) by Samuel G. Howe (1801–76), of Boston, was another triumph in pedagogics. The account of Laura Bridgman (1879) by Granville **Stanley Hall** (1846–), was the starting point of his pioneer work in child-study. The series of graded tests for mental retardation, introduced by Alfred **Binet** (1857–1911) and Theodore **Simon** in 1905–8, are now extensively used in school inspection and elsewhere to segregate defective children and adults. Stanley Hall's Adolescence (1904) and Aspects of Child-life and Education (1907), E. Claparède's Child Psychology (1909), Pastor K. H. G. Witte's Education of Karl Witte (1914), George W. Jacoby's Child Training (1914) Dr. Helen MacMurchy on the Organization and Management of Auxiliary Classes (Toronto, 1915) and Lewis M. Terman on the Intelligence of School Children (1919) may be mentioned. For the huge literature of child study and pedagogics, the reader must be referred to the bibliographies of Stanley Hall (1886), Arthur MacDonald (1899), W. H. Burnham (1914), J. T. MacManis (1916) and others.

Children's Hospitals.—The early history of children's hospitals goes back to the transition from the private, personal, egotistical charity of the Romans (enslavement of foundlings) to corporate charity under the influence of Christianity. This became dynastic under Constantine the Great (322 A.D.), patriarchal and clerical under Justinian (533), institutional with Guy of Montpellier (1180), corporate and non-clerical with the silk-makers of Florence (1211), state-institutional under Louis XIV (1670) and philanthropic and national in France and Russia at the end of the 18th century (Hügel).*

Archbishop **Datheus** founded the first authentic foundling asylum in 787 at Milan. This was followed by similar institutions at Bergamo (982), Laibach (1041), Padua (1097), Florence (Spedale di S. Maria della Scala, 1161), and the hospital founded by Guy and his Order of the Holy Ghost (1144) at Montpellier (1180). A bull of Innocent III states that this order had created nine foundling asylums in 1198. Another bull of the same Pope lists 29 foundling asylums in France under Philip IV (The Fair). Other asylums were founded at Arezzo (1188) and Florence (1193), and in 1198, Innocent III provided the *Conservatorio della Ruota*, in the Ospedale dello Santo Spirito in Rome, with accommodations for 600 foundlings, and a rotary contrivance (*ruota*) for receiving them at the door In the thirteenth century, asylums were founded at Parma (1201), Aix, Toulon, Novarra and Volterana (1201), Prato and Jerusalem (1210), Florence

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* Hügel, F. S., Beschreibung sämmtlicher Kinderheilanstalten in Europa, Vienna (1849), which contains a full account of children's hospitals in Europe up to the date of its publication. For the history of foundling asylums, see his "Die Findelhäuser und das Findelwesen Europa's." Vienna (1863).

(1218), Bellinzona (*circa*, 1250), Gimignano (1258), Lucca (1268), Embeck (1274), Cortona (1286) and Tauris (1294). In the fourteenth century, the Hôpital de l'Esprit Sainte was founded at Paris (1362), first for the reception of foundlings, later for legitimate children only (1422). This had been predeced by an institution of similar name, founded by Enrad Fleinz at Nuremberg (1331), and was followed by another at Venice (1380). On October 25, 1421, the famous Ospedale degl' Innocenti was founded at Florence, in 1426, the Pio Istituto degl' Esposti at Verona, and others at Genoa (1420), Bergamo (1438), Brescia (1447), Mantua (1449), Cremona (1450), Lodi (1458), Como (1468), Cremona (1479), and Munich (1489). In the sixteenth century, foundling and orphan asylums were erected at Locarno (1501), Reggio (1513), Naples (1515), Pistoja (1539), Paris (Hôpital de la Trinité, 1545), London (Christ's Hospital School, 1553), Piacenza (1573) and Amsterdam (1594).

It is not probable that any of the early medieval establishments were true hospitals (in the sense of being places where disease was actually treated) but merely places of refuge and shelter. It was only at the end of the fifteenth century, as Sudhoff has shown, when physicians began to give the inunction, sweating and guaiac treatment of syphilis in hospital, that the hospitals for "*curabiles, ergo curandi*" began to spring up alongside of hospitals set apart for incurable cases and isolation hospitals for lepers and epileptics.*

In 1639, **St. Vincent de Paul** (1576–1660), who had a worthy precursor in St. Thomas of Villanueva (1488–1555), moved the asylum founded by an unknown widow in the rue St. Landry, Paris ("La Couche," 1638) to the Faubourg St. Victor, to become the *Hospice des enfans trouvés* (1640) which was declared a public institution by Louis XIV, in June, 1670. Other foundling and orphan asylums existed at Hamburg (1604), Dresden (1618), Toledo (1629), Wurtzburg (1639), Peking (1662), Mainz (1665), Erfurt (1664, 1669), Brunswick (1677), Frankfurt (1679), Bremen (1692) and Berlin (1697); and in the eighteenth century at Prague (1704), Novgorod (1708), Hamburg (1709), Edinburgh (1732), Rio de Janeiro (1738), London (1739), Vienna (1742), Turin (1748), Strassburg (1748), Copenhagen (1753), Stockholm (1753), Moscow (1762), Petrograd (1770), Dublin (1781) and London (1789).

The first dispensary for children in Europe was that started by Dr. George **Armstrong** in London (1769–81). This was followed by the institution founded by Johann Joseph Mastalier in Vienna (1787), which was continued after his death by Leopold Anton Gölis (1794) and still exists. The Royal Sea-bathing Infirmary and National Hospital for Scrofula was founded at Margate, England in 1796. In 1785, at the instance of Louis XVI, a commission of the Académie des Sciences (Bailly, Laplace, Lavoisier, et al.) prepared a report on the wretched accommodations, appointments and hygienic status of the Hôtel Dieu, in which eight to nine children were found lying in one bed, with an almost total mortality. In 1788, J. R. **Tenon** made his famous report and recommendations for reforms in hospital construction and hygiene. As a result, the foundling asylum known as the "Maison de l'Enfant Jesus" (1751) was transformed into the present Hôpital des enfans malades (1802). This was for a long time, the largest children's hospital in Europe.† A children's dispensary was founded at Brünn by Dr. Ringolini (1810), Armstrong's London Dispensary was revived by John Bunnell Davis (1816) and followed by a hospital at Vienna (1826). The Nicholas Children's Hospital was founded at Petrograd by Dr. Friedeberg in 1834, the pediatric clinic in the Charité at Berlin in 1834. Others followed at Dresden (1834), Vienna (L. Mauthner, 1837), Budapest

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* Pagel-Sudhoff, "Einführung in die Geschichte der Medizing 2. Aufl." Berlin, (1915), p. 188.

† For the history of the Hôpital des enfans malades (1802–1913), see P. Lereboullet, Paris méd., XIV (1913–14), suppl., pp. 3–19.

(1839), Hamburg (1840), Stuttgart (1842), Prague (Kaiser Franz Joseph, 1842), Vienna (St. Joseph's, 1842), Moscow (1842), Frankfurt (1843), Turin (1843), Berlin (Elizabeth Hospital, 1843), Graz (1844), Berlin (Louisa Hospital, 1844), Lemberg (by regimental surgeon Brum, 1845), Stockholm (Pediatric Clinic, 1845), Turin (Ospedaletto di Santa Filomena, 1845), Copenhagen (Börnehospital by J. L. Dreyer, 1846), Munich (1846), Constantinople (1847).

Children's hospitals in England and America date from the middle of the nineteenth century. About 1849, Dr. Charles **West,** of London, attempted to convert the Royal Infirmary for Sick Children in Waterloo Bridge Road (1816) from a scattered set of dispensaries into a true hospital for sick children, but was frustrated by the professional jealousy of his colleagues. In spite of these rebuffs, he visited all the London hospitals, wrote to all the continental children's hospitals for data, and through the social prestige of Bence Jones, he at length secured a footing and a fund for his project. After much opposition and many disappointments, after West had travelled over France and Germany for further information, the Hospital for Sick Children in Great Ormond Street was opened (February, 1852), in a house which had once been occupied by the celebrated Dr. Richard Mead. Mead's drawing room, with its painted shepherds and shepherdesses, became the girl's ward, and his museum the out-patient department. Dr. West and his wife did all the furnishing. West himself organized the system of accounting, the diet table, the Samaritan Fund, the system of boarding out in cottages, the Museum of Anatomy, drew up the catalogue, acted as physician-in-chief and later started an infant nursery or crèche and a convalescent branch in Cromwell Street. The hospital thus accommodated 75 patients and 52 convalescent patients. During 1852, it took in 143 patients and 1250 out-patients, during 1871, 998 patients, and 11,988 out-patients, during 1852–71, 10,442 patients and 200, 691 out-patients. Dr. West resigned in 1875, and did not apply for his position again, but when the hospital was rebuilt (in 1875), he furnished it again throughout and gave it his library and pathological drawings.* A brilliant account of the Hospital was written by Charles Dickens in 1852. Dicken's speech of February 9, 1858, in behalf of this institution is one of the finest specimens of his genius. Miss Mulock, Tom Hood and others also lent their pens to its aid. The hospital was further enlarged in 1892, 1899 and 1908, and now has 240 beds, a Private nursing institution, a medical school in affiliation with London University, at which Garrod, Still, Poynton and Hutchinson are teachers, a casualty department and the largest out-patient service in the world.

The other children's hospitals of London are the Kensington Dispensary (1840, rebuilt 1901), The Belgrave (1863, 1903), Grosvenor (1866), Victoria, Chelsea (1866), Northeastern (Queen's), Bethnal Green (1867), Alexandra (Hip Disease, 1867, 1894), East London (1868), Evelina (1869), Sydenham Road (1872), Cheyne, Chelsea (1874), St. Monica's Home (1874), Paddington Green (1883, 1895, 1911), St. Mary's Plaistow (1893), Infant's Hospital, Vincent Square (1903, ,1907), Woolwich (1905), Queen Mary's (1907) and Park Hospital, Lewisham (1910). The largest of these are the East London and the Evelina. The Provincial children's hospitals of England are: Kidderminster (1821, 1870), Manchester (1829, 1903, 1907, 1912), Liverpool Infirmary (1851, 1868), Leeds (1853), Jenny Lind Infirmary, Norwich (1853), Manchester (1855), Bristol (1857, 1885), Newcastle (1861, 1888), Sunderland (1864), Gloucester (1867), Brighton (1868), Nottingham (1869), Birkenhead and Wirral (1869), Hull (1872), Sevenoaks (1872), Cheltenham (1874, 1901), Sheffield (1876, 1896, 1902, 1906), Derbyshire (1877), Bradford (1883), Newbury (1886), Gateshead (1887) Rosehill (Babbicome, 1888, Torquay, 1902), Heswall, Cheshire (1899, 1908).

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* Brit. Med. Jour., London, i (1898), p. 922.

In Scotland: the Royal Edinburgh (1859, 1895), Royal Aberdeen (1897), Edinburgh (1878, 1885), and Royal Glasgow (1883). In Ireland, the National, at Dublin (1821), the Dublin Children's Hospital (1872, 1874), Ulster, Belfast (1872, 1911–12), Belfast (1873, 1885) and Victoria, Cork (1874). In Canada: Toronto (1875). In India: Bombay (1876). In Australia, those at Melbourne (1870), Adelaide (1876), Brisbane (1877), Rockhampton, Queensland (1885) and Perth, West Australia (1909).

Among the many children's hospitals founded on the continent of Europe after 1850 are those at Stettin (1851), Paris (Sainte Eugénie, 1854), Stockholm (Crown Princess Louisa, 1854), Wildbad-Ludwigsburg (1854), Leipzig (C. Hennig's Polyclinic, 1855), Petrograd (1855), Basel (1862), Berne (Jenner, 1862), Amsterdam (Emma, 1865), Zürich (1868) Petrograd (Prince Peter Oldenburg, 1869), Havre (1875), Vienna (Kronprinz Rudolf, 1875), Cracow (St. Ludwig's, 1876), Dresden (1878), Helsingfors (1879), Vienna (Carolina, 1880), Cremona (1881), Naples (Lina, 1881), Madrid (Infant Jesus, 1882), Oporto (Maria Pia, 1883), Moscow (St. Olga, 1887), Berlin (Kaiser und Kaiserin Friedrich (1890), Genoa, 1890), Leipzig (1893), Dürkheim (1894), Constantinople (Hamidié, 1898), Athens (St. Sophia, 1900), Nancy (J. B. Thierry, Maxésville, 1900), Paris (Bretonneau, 1900, Trousseau, 1900, Pasteur, 1900), Paris (Hérold, 1901), Parma (1901), Paris (Polyclinique H. de Rothschild, 1902), Berlin, University Clinic, Charté 1903, Bordeaux (suburban hospital at Bouscat, 1903), Cremona (1904), Rostock (Clinic, 1905), Lodz (1906), Budapest (1907), Frankfurt am Main (Annie Stiftung, 1908), Lublin (1911), Vienna (New University Hospital, 1911), Venice (Umberto, 1912) and Warsaw (1912).

In 1852, one "Philopedos," an ex-dispensary physician of New York City published "A Few Remarks about Sick Children, and the Necessity of a Hospital for them." Like the hero of the old Spanish play, Philopedos remained *un hombre sin nombre*,* but this particular *hombre*, through his insistence upon the high mortality of infants from ill-ventilated, unsanitary habitations and the crowded condition of the general hospitals, was instrumental, as Adams says "in establishing the Child's Hospital and Nursery—the first hospital devoted to children on this continent—which was organized March 1, 1854, and stands to-day as a monument to this unknown writer."† This hospital was also a maternity at the start. The first institution designed exclusively for children was the Children's Hospital of Philadelphia, established in the following year (1855).

Among the later American children's hospitals are those at Chicago (Mary Thompson, 1865), Boston (1869, rebuilt, 1914), New York Foundling (1869), New York (St. Mary's 1870), New York Free Dispensary (1871), Washington, D. C. (1871), Radnor, Pa. (1873), Atlantic City (1873), Albany (1875), Lawrence, Mass. (1875), San Francisco (1875), Philadelphia (St. Christopher's, 1876), Philadelphia (Children's Homœopathic, 1877), St. Louis (1879, rebuilt, 1914), Boston (Infant's, 1881), Cincinnati (1883), St. Louis (Martha Parson's Free, 1884), Chicago (Children's Memorial, 1884), Baltimore (Thomas Wilson Sanitarium,

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* Tirso de Molina, El Burlador de Sevilla, act I, sc. I.

† Adams, S. S., Tr. Am. Pediat. Soc., N. Y., ix (1897), p. 23.

1884), New York (Laura Franklin, 1886), San Francisco (1886), Detroit (1887, 1896), New York (Babies,' 1887), Syracuse (1887), Buffalo (1892), Columbus, Ohio (1892), Milwaukee (1892) and Los Angeles (1913). The Baby's Hospital of Philadelphia (1921) is a social service center, combining a small pediatric ward with a research institute, a new departure in the matter of raking pediatric service to the people. The many seaside hospitals and stations for tuberculous children can only be referred to. There are no less than 18 on the Italian coast alone.

Clinical instruction in pediatrics was first introduced by Rosenstein in Sweden (Jacobi). In 1761, the chief physician of the Lying-in Hospital of Stockholm was ordered, by royal mandate, to lecture on infantile diseases (Medin). During the nineteenth century, pediatric teaching was for a long time exploited by means of lectures, in which, of course, such men as Trousseau, Roger, Bouchut and Parrot in Paris, Charles West in London, the Viennese clinicians (Mayr, Widerhofer, Escherich), and in Berlin, Henoch and Gerhardt were most effective teachers. On April 2, 1845, T. T. Berg was appointed professor of pediatrics in the Karolin Medico-Chirurgical Institute and on May 2, 1845, a pediatric clinic was opened at the Central Home for Children. In America, Jacobi introduced bedside teaching in his earliest courses (1862–64). This was revived in 1898, when Jacobi's pupil, Francis Huber, supplied the funds for a special service of bedside teaching at the Roosevelt Hospital for the benefit of the pupils of the College of Physicians and Surgeons. In 1910, Mrs. A. Woerishoffer donated $100,000 for the foundation of the Jacobi Division of the German Hospital, in charge of Dr. A. L. Goodman. This, Jacobi characterizes as the third phase of bedside teaching in pediatrics. In the Paris Faculty, says Hutinel, "Roger (1853) taught as a clinician, Parrot (1878) as an anatomist, Grancher (1885) as a hygienist." During Parrot's incumbency at the Hôpital des enfants assistés, the cradles of the nursling patients were jumbled closely together, without regard to possibilities of infection, the same half-wiped spoon served to examine all throats, the same thermometer, barely wiped upon an apron, served for all rectal temperatures, the bed-linen was never disinfected, the mattresses were soiled with dejecta, the milk, in open crocks, absorbed all dust at sweeping, and the crying infant was quieted by a piece of crumbled biscuit knotted in a rag, dipped into a jar containing a gummy syrup. The aphthæ, vomiting, diarrhea and fever which resulted from this régime were dubbed by Parrot "athrepsia." With the advent of Grancher (1885), a new order of things obtained. Forks, spoons, goblets and other utensils were sterilized, bed-linen and floors were disinfected, the personnel were required to keep themselves clean and not approach an infectious case without donning a surgical blouse beforehand.* Much was learned about the management of infectious cases from Grancher's wire cages about the beds (1889), which were displaced by the system of glass boxing (*boxes vitrés*) of Hutinel (1894), a system frequently copied, especially in von Pirquet's clinic in the New University Children's Hospital at Vienna. The leading Parisian clinics are those of Hutinel at the Hôpital des enfants malades, Variot at the Hôpital des enfants assistés and Netter at the Hôpital Trousseau. In London, Still's great outdoor service at the Great Ormond Street Hospital is the largest in existence. More than 3000 in-patients and as many as 100,000 out-patients are sometimes treated annually. Sir Robert Jones's clinic at Liverpool is a great centre for infantile orthopedics. In Leipzig, Heubner had, at the start, only a district polyclinic, but through his exertions, a new Children's Hospital (1893), with clinic was acquired. Although the French, Swiss and Austrian medical faculties are all provided with pediatric clinics, only ten of the twenty German universities were so provided in 1910, and, in only eleven was instruction given by a professional pediatrist.* At Berlin, the science of infant nutrition, as taught by Finkelstein and Meyer, is the feature of pediatric instruction. At Munich, Pfaundler's clinic is one of the best ever organized. He has claimed that he has more assistants than patients. This clinic is eminently modern in intention, devoted mainly to prophylaxis and infant welfare. At the Milk Station, modified milk and tea are given out freely to the poor. Bottles are sterilized by means of a gigantic wheel arrangement. The Normal Infant Clinic is designed, like that of Toronto, to keep the infant in sound health from day to day. In the United States, very superior instruction has been given by such able organizers as Rotch and Morse (Boston), Jacobi, Holt, and Chapin (New York) Howland (Baltimore), Abt (Chicago), Lucas (San Francisco), Sedgwick (Minneapolis), Hoobler (Detroit), Cowie (Ann Arbor), Veeder (St. Louis), and by such men as Northup in the Presbyterian Hospital and Koplik in Mount Sinai Hospital (New York).

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* Hutinel, L'enseignement de la pédiatrie à la Faculté de Paris. Ann. de méd. et chir. infant., Paris, xii (1908), pp. 37–50.

Pediatric Societies and Periodicals.—In 1860, the New York Academy of Medicine attempted to form a section for Diseases of Children, but after a few tentative meetings the project was abandoned, and not until 1887 was the present Pediatric Section organized, with J. Lewis Smith as chairman. Meanwhile, the American Medical Association organized a special Pediatric Section in 1880, with Dr. A. Jacobi as its first chairman, and this has continued to date. The British Medical Association has a similar arrangement, but the meetings of the section have not been annual but occasional. In 1883, the Gesellschaft der Naturforscher und Aerzte established a pediatric section, meeting annually. In the same year, the *Gesellschaft der Kinderheilkunde* was founded (September 18, 1883) by Gerhardt, Henoch, Demme, Steffen, Soltmann and others, holding its first meeting at Freiburg. The first presidents were Steffen (1883–1900), Heubner (1900–1906) and Escherich (1906). The transactions (*Verhandlungen*, 1883–1913) are of a high order of merit. A Milk Commission of the Society was formed by Soltmann, Biedert, Heubner and Escherich in 1897. Russian pediatric societies were founded at Moscow (1885) and Petrograd (1892), and publish transactions. The American Pediatric Society was organized in 1888, with Dr. A. Jacobi as its first president, his successors in office being J. Lewis Smith, Rotch and Osler. This society is an exclusive organization of the type described by Weir Mitchell: "a meeting of men whose power to teach others is a pledge to that humility which is ever seeking to learn. It has no medical politics, nor is it embarrassed by useless idlers who look upon such gatherings as merely pleasant social meetings."† Its membership is limited to 75 and confined to the serious workers of scientific type. The Transactions (1888–1921) contain the best kind of pediatric literature. Several local American pediatric societies have been formed, notably the Ohio State Pediatric Society (1895), the Bethesda Pediatric Society of St. Louis (1895), the Philadelphia Pediatric Society (1896), the Indiana State Pediatric Society (1897), the Chicago Pediatric Society, the Central States Pediatric Society, and the New England Pediatric Society. There is also the National Association for the Study and Education of Exceptional Children (1905), the Association of American Teachers of Diseases of Children (1907), the American School Hygiene Association (1907), the American Association of Medical Milk Commissions (1907) and the American Association for the Study and Prevention of Infant Mortality (1909). which became the American Child Hygiene Association in 1919. The Society for the Study of Diseases of Children, established at London in 1900, has, since November 27, 1908, been merged into the Section for the Study of Diseases of Children of the Royal Society of Medicine (Reports of Society, 1900–1908, Proceedings of Section, 1908–21). The Société de pédiatrie of Paris was established in 1899, and has published Bulletins to date. A French Congress of gynecology, obstetrics and pediatrics was held at Bordeaux in 1895 and published *Mémoires* for several years. An Italian pediatric congress (Congresso pediatrico italiano) was organized in 1890 and published *Atti* for a number of years. Every International Medical Congress (1867–1913) has had a pediatric section. An International Congress of Pediatrics was held at Paris on October 7–9, 1912, and has published its *Comptes-rendus* (Paris, 1913).

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* Feer, E., Arch. f. Kinderheilk., Stuttgart, lii (1909–10), pp. 244–259.

† Mitchell, Tr. Cong. Am. Phys. & Surg., ii (1892), p. 159.

The first International Congress of School Hygiene was held at Nuremberg in 1904. An International Milk Federation (*Fédération internationale de la laiterie*) has held Congresses at Brussels (1903), Paris (1905), The Hague (1907), Budapest (1909) and Stockholm (1911). A *Union internationale pour la protection de l'enfance du premier âge*, has for its function the organization of Congresses of Milk Stations, has held one Congress at Budapest (1905) and is the parent of International Congresses for the Study and Prevention of Infant Mortality held at Paris (1905), Brussels (1907) and Berlin (1911).

According to Crozer Griffith,* the earliest periodical to be concerned with pediatrics was the *Archiv für die Geburtshilfe, Frauenzimmer- und neu-gebohrner Kinderkrankheiten,* started at Jena in 1787. The first periodical devoted exclusively to pediatrics was the *Analekten über Kinderkrankheiten* (Stuttgart, 1834–37). A *Clinique des maladies des enfants* of the Strassburg Faculty for 1837–41 was edited by V. Stöber in 1841. *La Clinique des hôpitaux des enfans,* with Vanier as editor, was published at Paris in 1841–44. The Children's Hospital at Dresden published a *Jahrbuch* for the year 1844–45. The *Jahrbuch für Kinderheilkunde* was started at Vienna in 1857, with F. Mayr as editor and has been continuous to date. The *Archiv für Kinderheilkunde* (1870), the *Kinder-Arzt* (1890) and the *Centralblatt für Kinderheilkunde* (1896) followed. The *Revue mensuelle des maladies de l'enfance* (1883), and the *Archives de médicine des enfants* (1898) are prominent in France. The *Archives of Pediatrics* was started in New York by William Perry Watson in 1884, and *Pediatrics* by George Carpenter in 1895. La *Pediatria* was started at Naples by Francesco Fede in 1893. The monthly *Dietskaya meditsina* (Moscow, 1896–1903) was in its time the principal Russian periodical.

The *British Journal of Children's Diseases* was established in London by George Carpenter in 1904. The *American Journal of Diseases of Children,* the best pediatric periodical in English was started in 1911.

A list of pediatric journals and transactions, arranged in chronological order is subjoined:

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* Crozer Griffith, J., P. "Jour. Am. Med. Assoc." Chicago XXI (1898) pp. 947–951.

PERIODICALS AND TRANSACTIONS DEVOTED TO PEDIATRICS EXCLUSIVELY

Bibliothek für Kinderärzte. v. 1. 8°. Vienna (1792).

Analekten über Kinderkrankheiten. ed. Riecke. Hfte. 1–12. 4 v. 8°. Stuttgart (1834–37).

Clinique (La) des hôpitaux des enfants. ed. Paul Prosper Vanier. v. 1–4. 8°. Paris (1841–44).

Journal für Kinderkrankheiten. ed. Barthez, Berg [*et al.*] v. 1–59. 8°. Berlin (1843–7); Erlangèn (1848–72).

Oesterreichische Zeitschrift für Kinderheilkunde. ed. B. Kraus and L. Mauthner. v. 1–2. 8°. Vienna (1855–57).

Jahrbuch für Kinderheilkunde und physische Erziehung. ed. Fr. Mayr. v. 1–8. 8°. Vienna (1857–66); n.F. ed. Prof. Binz [*et al.*]. v. 1–97. Vienna (1867–1922).

Jahrbuch für Physiologie und Pathologie des ersten Kindesalters. ed. Ritter von Rittershain. v. 1. 8°. Prague (1868).

Oesterreichisches Jahrbuch für Paediatrik. ed. Ritter von Rittershain and Maximilian Herz. v. 1–8. 8°. Vienna (1870–77).

Central-Zeitung für Kinderheilkunde. ed. Adolf Baginsky and Alois Monti. v. 1–2. 40. Berlin (1877–79).

Archiv für Kinderheilkunde. Founded by Adolf Baginsky, M. Herz, A. Monti (1880–92); ed. Baginsky, Monti and A. Schlossmann 1892–1922. v. 1–71. 8°. Stuttgart (1880–1922). Current.

Gesellschaft für Kinderheilkunde. Verhandlungen. v. 1–30. 8°. (1883–1913).

Revista de enfermedades de niños. Redactada por el cuerpo facultátivo del Hospital del Niño Jesus. v. 1. 8°. Madrid (1883).

Archivio di patologia infantile. ed. Luigi Somma. v. 1–6. 8°. Naples (1883–88) .

Bulletin hygiénique et statistique des enfants du ler âge de la ville d'Algér . . . ed. A. Jobert. No. 1, v. 1. 8°. Alger (1883).

Revue mensuelle des maladies de l'enfance. ed. Cadet de Gassicourt and L. A. de Saint-Germain. v. 1–25, Paris (1883–1907). 8°.

Archives (The) of Pediatrics. ed. William Perry Watson. v. 1–39. 8°. Jersey City, N. J. (1884); Philadelphia (1884–91); New York (1892–1922).

Archivos de medicina y cirugía de los niños. ed. Baldomero Gonzalez Alvarez. v. 1–5. 8°. Madrid (1884–89).

Obshtshestvo Dietskich Vrachei v. S.-Peterburg. Trudi I–X (1885–96). [Society of Pediatricians . . . Memoirs.] 8°. St. Petersburg (1887–96).

Archivio italiana di pediatria. ed. Giuseppe Somma. 2 s. v. 7–12. 8°. Naples (1889–94). Ended.

Revista de enfermedades de la infancia. ed. Jaime Guerra y Estape. v. 1. 8°. Barcelona (1890).

American Pediatric Society. Transactions. 8°. [Philadelphia] (1890–1922). Current.

Beiträge zur Kinderheilkunde aus dem I. öffentlichen Kinderkrankeninstitute in Wien. 1.–3. Hft., n.F. v. 1–5. 8°. Vienna (1890–93).

Congresso pediatrico italiano. Atti. 1 (1890); 2 (1892); 3 (1898); 4 (1901). 8°. [v.p.] (1891–1902).

Kinderarzt (Der). Zeitschrift für Kinderheilkunde. ed. M. Sonnenburger. v. 1–31. 8°. Berlin and Neuwied; Leipzig (1890–1920).

Boletin del Dispensario y Hospital de niños pobres de Barcelona. ed. Juan Roca. v. 1–7. fol. Barcelona (1891–97).

Igiene dell' infanzia e medicina preventiva. ed. Francesco Rugieri. v. 1–5. 8°. Rome (1892–96).

Obshtshestvo Dietskich Vrachei sostoyashtshiy pri Imperatorskom Moskovskom Universitetie. Trudi . . . v. 1–7 (1892–3 to 1898–9) [Society of Pediatricians at the Imperial Moscow University. Memoirs . . .] 8°. Moscow (1892–99).

Journal de clinique et de thérapeutique infantiles. ed. G. Variot. v. 1–7. Paris (1893–99). Merged in Gazette des maladies infantiles.

Nederlandsche Vereeniging voor Pædiatrie. Voordrachten. . . v. 1–2. 8°. Utrecht (1893–6).

Pediatria (La). ed. Francesco Fede. R. Jemma. v. 1–30. 8°. (1893–1922). Current.

Médecine (Là) infantile. ed. Jules Comby. v. 1–4. 8°. Paris (1894–97).

Centralblatt für Kinderheilkunde. ed. Eugen Graetzer. v. 1–20. 8°. Leipzig, (1896–1915). Current. In 1908, title became; Zentralblatt etc.

Dietskaya meditsina. ed. L. P. Alexandroff. v. 1–8. 8°. Moscow (1896–1903). Ended.

Pediatrics. ed. by Dillon Brown, George Carpenter (*et al*). v. 1–28. 8°. New York and London (1896–1916).

Annales de médecine et chirurgie infantiles. ed. E. Périer. v. 1–18. 8°. Paris (1897–1914).

Médecine (La) infantile. ed. E. Périer. H. Roueche v. 1–27. 8°. Paris (1987–1911).

Pratique (La) de la médecine infantile. ed. E. Périer. v. 1. 8°. (1897).

Archives de médecine des enfants. ed. F. Brun, J. Comby [*et al.*] v. 1–25. 8°. Paris (1898–1922).

Gyermekgyogyaszat [Pediatry]. v. 1–10. fol. and 8°. Budapest (1898–1907). Supplement to: Órvosi hetilap.

Infanzia anormale. Bulletino ufficiale della Società italiana pro anomali. v. 1–14. 8°. Milaro, 1898–1921.

Tuberculose (La) infantile. ed. Léon Derecq and Henri Barbier. v. 1–10. 8°. Paris (1898–1907).

Conferenze d'igiene infantile tenute per cura del Comitato romano della Società Nazionale Pro Infantia nell' aula dell' Isituto d'igiene di Roma nell' anno (1898). 230 pp., 1 1. 8°. Rome, G. Balbi (1899).

Gazette des maladies infantiles. Journal de pædiatrie. ed. H. Barbier and Villemin. v. 1–14. 4°. Paris (1899–1912). In January, 1900, Journal de clinique et de thérapeutique infantiles merged in this journal, and title became: Gazette des maladies infantiles et Journal de clinique et de thérapeutique infantiles réunis.

Société de pédiatrie de Paris. Bulletins. v. 1–19. 8°. Paris (1899–1921).

Igiene dallà prima infanzia. Atti del primo Congresso nazionale per l'igiene dell' allattamento mercenario (1899). 8°. Milan (1900).

Paedologisch Jaarboek. ed. M. C. Schuyten. v. 1–5. 8°. Antwerp (1900–1904).

Society for the Study of Disease in Children. Reports (1900–1901 to 1907–8). v. 1–8. 8°. London (1901–99).

Congresso per l'igiene dell' allattamento e la tutela della prima infanzia, tenuto in Firenze (1901). Atti. 8°. Florence (1903).

Homœopathic (The) Journal of Pediatrics. ed. J. G. Chadwick. v. 1. Buffalo, N. Y. (1902).

Archivo di patologia e clinica infantile. ed. Tommaso Guida. v. 1–2. 8°. Naples (1902–3).

Gesellschaft für innere Medizin und Kinderheilkunde in Wien. Mitteilungen. v. 1–21. 8°. Vienna (1902–22). Current.

Monatsschrift für Kinderheilkunde. ed. Arthur Keller. v. 1–22. 8°. Leipzig and Vienna (1902–1922).

Revue d'hygiène et de médecine infantiles, et Annales de la polyclinique H. de Rothschild. ed. H. de Rothschild. v. 1–10. 8°. Paris (1902–11).

Congresso nazionale "pro infantia" in Torino (1902). Atti. 8°. Turin (1903).

Gyermekorvos. [The children's physician.] v. 1–12. 4°. Budapest 1903–14). Supplement to Budapesti orvosi ujsag.

Pédiatrie (La) pratique. ed. E. Ausset. v. 1–12. sm. 4° (1903–13).

Rivista di clinica pediatrica. ed. C. Comba, [*et al.*] v. 1–20. 8°. Florence (1903–21).

British (The) Journal of Children's Diseases. ed. George Carpenter. J. D. Rolleston. v. 1–19. 8°. London (1904–22). Current.

Halbmonatsschrift für Frauen- und Kinderkrankheiten. ed. S. Schick. v. 1–2. 8°. Vienna (1904–5).

Philadelphia Pediatric Society. Transactions (1904–5, 1905–6). 8°. New York (1905–6).

Archivos Latino-Americanos de pediatria. v. 1–13. 8°. Buenos Aires (1905–1919).

Jikwa Zasshi [Journal of Pediatrics.] Nos. 75–78. 8°. Tokyo (1906).

Zeitschrift für Kinderheilkunde. ed. H. Finkelstein [et al] Original. Zeitschrift für Kinderfflege. v. 1–9. 8°. Berlin, 1906–14. Referate: Zentralblatt für die gesamte Kinderheilkunde ed. H. Finkelstein v. 1–12. 8°. Berlin (1910–22) Current.

Przeglad Pedyatryczny [Pediatric Review] v. 1–6. 8° Krakow, 1908–14.

Rassegna di pediatria. v. 1–5. 40. Parma, 1910–14. Pediatriya. v. 1–6. 8°. Petrograd, 1911–14.

Pediatría (La) española. v. 1–11. 8°. Madrid (1912–22). Current.

Association internationale de pédiatrie; premier congrès tenu à Paris, les 7, 8, 9, Octobre (1912). 8°. Paris (1913).

Le Nourisson, ed. A.-B. Marfan. v. 1–10. 8°. Paris, 1913–22.

COMBINED OBSTETRIC GYNECOLOGIC AND PEDIATRIC PERIODICALS

Archiv für die Geburtshülfe, Frauenzimmer- und neugebohrner Kinderkrankheiten. v. 1–6 (à 4 Stücke) 8°. Jena (1787–96). Continued by the following.

Neues Archiv für die Geburtshülfe, Frauenzimmer- und Kinderkrankheiten. v. 1 (à 4 Stücke). 8°. Jena (1798–1800).

Annalen der Geburtshülfe, Frauenzimmer- und Kinderkrankheiten. Für die Jahre (1790 und 1791). ed. Jacob Römer. 2v. 8°. Winterthur (1793–94).

Annalen der klinischen Anstalten der Universität zu Breslau, für Geburtshülfe und Krankheiten der Weiber und Kinder. ed. J. W. Betschler. v. 1–2. 8°. Breslau (1832–34).

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THE TWENTIETH CENTURY

Social or Preventive Pediatrics

"Spake I not unto you, saying: Do not sin against the child," Genesis, XLII, 22.

In the twentieth century, pediatrics was elevated from its ancillary status as a "dependent dwarf" of ordinary medical practice, into the larger atmosphere of social medicine, of which it is now one of the most important independent branches. This was due to the menace of infant mortality as the chief cause of the depopulation of modern states, with the consequent extension of the science of infant nutrition and metabolism and the creation of the new science of infant welfare, as ways and means of combatting the evil. It has been the universal experience in all times and places, that the mortality of hand-fed infants is higher than that of the breast-fed. In this regard, it is highly significant, as Heubner says, that while the science of infant diseases and their treatment is a plant of almost recent growth, the generic idea of the importance of infant welfare, as the basis of racial or national hygiene, has excited human interest from time immemorial. The modern movement is only the logical expansion of a folk-intuition or *schwebender Gedanke,* which exists, in crude form, even among semi-civilized peoples.

THE SCIENCE OF INFANTILE (NUTRITIONAL) DISORDERS*

Through the work of Bichat, as we have seen, the attention of Billard and other pediatrists of his time was directed to the post-mortem lesion as the basis of classification of infantile diseases; and this tendency, gathering impetus from the massive achievement of Virchow and Rokitansky, continued straight on to the latter part of the nineteenth century. In other words, it was nowise perceived that post-mortem findings are but end-results of a long series of chemical changes within the body, and that the true cause of disease and basis of classification is to be sought in the initial rather than the final state of these changes. Thus, the classification of gastro-intestinal diseases in infancy was for a long time confused by the Broussais theory of gastro-enteritis and irritation as the basis of pathology, and the concept "softening of the stomach," which John Hunter, and latterly Heubner himself, defined as mere post-mortem auto-digestion (an end-result), was accepted in Billard's time, as a clinical and pathological "entity." Bednar described the various toxemias of infancy with care (1850–53) but he did not see their relation to the disorders of infant nutrition (Heubner).

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* In attempting to deal with the complex subject of infant nutrition and metabolism, I wish to acknowledge my indebtedness to the address of O. Heubner; "Zur Geschichte der Saüglingsheilkunde" (Berlin, 1909), and to the valuable information conveyed by Drs. Isaac A. Abt (Chicago), John Ruhräh (Baltimore) and John Foote (Washington, D. C.).

An apparent step forward was taken when Parrot maintained that severe diseases of infants lead back to some mysterious deep-lying disturbance or "athrepsia," of the whole infantile organism; but Parrot, as Heubner points out, did not reason in terms of metabolism, but again considered only post-mortem findings, and Hutinel maintains that the cause of athrepsia was simply hospital sepsis and the dirty hands of the attendants. The expression "metabolic phenomena" was first employed by Theodor Schwann in 1839 (Fraser Harris). The generic concept (*Stoffwechsel*) was made more familiar in the "Organic Chemistry" of Liebig (1842), who classified the organic foodstuffs, made a thorough investigation of the metabolism of mineral salts, and even made some attempt to improve infant nutrition by the addition of digestible carbohydrates to animal milk as a substitute or "surrogate" for maternal milk (Liebig's Food). In 1837, L. T. W. Bischoff first demonstrated the presence of free oxygen and CO_2 in the blood and studied the urea as a measure of chemical interchange in the body. In 1838, Johann Friedrich **Simon** [1807–43], of Berlin, made a chemical and physiological investigation of human milk in comparison with animal milk.* This, in the opinion of Heubner, is the first real landmark in the exact science of infant metabolism as a basis for rational infant nutrition. The investigation passed unnoticed for some thirty years. "The fundamental concept of disease remained fast-rooted in the anatomical lesion, the theory of treatment conscientiously limited itself to a number of drugs designed to combat that lesion" (Heubner). But the general idea that disorders of infant nutrition are to be treated not by drugs but by correct diet was gaining ground, and the work of Biedert, Jacobi, and others on infant nutrition was not without results. The pediatrists of the Vienna school, Mayr and Widerhofer, attained the most refined semeiology in their

* Simon, J. F., De lacte muliebris ratione chemica et physiologica, Berlin dissertation (1838). Also, German translation, Die Frauenmilch, etc., Berlin, (1838).

clinical delineations, through the use of instruments of precision. Küttner, a Dresden pediatrist of the same type, said frankly "He who would cure sick children must, before all else, know how to feed them." Franz **Soxhlet** furthered the cause of pure milk by introducing the idea of "surgical asepsis in the hygiene of cow-stalls" and the sterilization of milk (Heubner). Epstein and Grancher carried over the same asepsis into the children's wards. In 1878, the obstetrician Friedrich **Ahlfeld** (1843–), at Leipzig, introduced the use of the balance in weighing infants in connection with growth and metabolism;* and a number of women physicians established the basic data by weighing their own infants at suckling during the whole period of lactation. This led to an entirely new concept, that of the "nutritive requirement," of the suckling infant. In the meantime, Carl **Bergmann,** in 1847, emphasized the relation between heat production and surface area of the body,† which was also to be forgotten until Rubner again brought it forward (1883); Voit and Pettenkofer estimated the amounts of proteins, fats or carbohydrates broken down in the body (from the total nitrogen and carbon dioxide eliminated) by a special respiration chamber (1861); and Voit introduced new methods for determining the intake and outgo in the balance of nutrition and the amount of proteid necessary in foods. Paul **Zweifel** demonstrated pepsin in the stomach and diastase in the parotid of the newborn (1874).‡ Joseph **Forster,** in the earliest investigation of the gaseous metabolism of the new-born, made with a Pettenkofer-Voit respiration chamber, showed that the infant produces more CO_2 per unit weight than the adult (1877).§ Epstein studied the duration of gastric digestion in infancy (1880–87). Johann **Kjeldahl** introduced his method of estimating nitrogen content in (1883). Max **Rubner** found, that the metabolism is proportional to the surface energy of the body (1883) and investigated metabolic changes in terms of heat and energy units by calorimetry (1891–1902). Wilhelm **Camerer** introduced the scientific investigation of infantile metabolism in the pediatric clinic (1894). Improved calorimeters, such as those of d'Arsonval (1886), Atwater and Rosa (1897), Atwater and Benedict (1905) were invented; and, in 1898–99, **Rubner and Heubner** published their epoch-making monographs on the average daily food requirements of the normal and the atrophic infant, which are the starting point all of modern work on infant metabolism. The theory of disordered infantile nutrition now followed three distinct and separate trends. **Escherich,** in 1886, first signalized the importance of the bacterial flora of the intestine as pathogenic agents in infantile disease (1885) and postulated an infectious, endogenous, toxic gastroenteritis or milk-infection (1900), although no specific bacillus was found. **Czerny and Keller** maintained that disturbances of nutrition may spring from overfeeding, especially with fats, from infection (enteral and parenteral), from inborn defective metabolism (exudative diathesis), and from congenital defects. Czerny drew attention from pathological processes in the intestinal tract to the intermediate metabolism in outlying organs and cells of the body; and the fact that nitrogen was excreted in the urine as ammonia instead of urea suggested an abnormal excess or an insufficient breaking down of acids in the organism. Schlossmann taught the straight doctrine that artificial feeding is "unnatural feeding." Finkelstein, reasoning from clinical appearances, argued that infantile diseases are due to disturbances of balance of nutrition, to dyspepsia (diminished tolerance), to decomposition (Parrot's athrepsia) and to intoxication (enterocatarrh, cholera infantum). In 1906, **Finkelstein** opposed the Biedert theory that casein is harmful, the Czerny theory that fats are harmful, the Escherich theory that bacteria are harmful in the infantile digestive tract, and the Rotch theory of percentage feeding to offset the harmfulness of proteids, and advanced the theory of an alimentary fever from sugar or salt, with a special "albumen milk," to meet these conditions. Finkelstein's *Eiweissmilch*, a mode of therapy rather than an infant food, shows that proteids are not necessarily harmful, but his theory of salt- and sugar-fevers was opposed to such purpose that he himself ultimately abandoned his dogmatic position as to the pyrogenic action of carbohydrates, and finally came around to Czerny's view that fats are more harmful than casein in a bowel previously irritated by sugar fermentation (1910). Ingestion of sugar has been pushed to the point of "sugar-diarrhea" by Orgler (1908), Allen (1913), Talbot and Hill (1914), without any evidence of sugar intoxication. The chief danger of sugar to the infant would appear to be that it is a culture-medium for the growth of bacteria in the intestinal tract. But, whatever viewpoint is assumed, the mystery of the disorders of infant metabolism, which cause the baby to die incontinently or to sink helplessly into dissolution, is still to be unravelled, as Heubner says, in the conditions leading to a pathological lesion of the infantile intestinal tract.

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* Ahlfeld, "Ueber Ernährung des Säuglings an der Mutterbrust; fortlaufende Wägungen während der Säuglingsperiode." Leipzig (1878).

† Bergmann, "Ueber Verhältnisse der Wärmeökonomie der Thiere zu ihrer Grösse," Göttingen (1848).

‡ Zweifel, "Untersuchungen über den Verdauungsapparat der Neugeborenen," Berlin (1874).

§ Forster, "Amtl. Ber. d. 50. Versamml. deutsch. Naturf. u. Aerzte," München (1877), p. 355.

The subject of infant metabolism and nutrition has been a debateable land, made up of the shifting sands of theory. The history of metabolism itself may be likened to a succession of dissolving views. The assemblage of the different theories has all the effect of Schopenhauer's concert of Russian horns, each player producing (in his place) a single isolated note. Ruhräh likens the different ways of approaching metabolism to Saxe's poem "The Six Blind Men and the Elephant." The energy-metabolism is computed1) by measuring the heat lost in the calorimeter,2) by obtaining the heat from the respiratory quotient (volume of oxygen inspired into volume CO_2 expired) in a respiration chamber. The basal metabolism (at absolute rest) is hard to compute in infants, on account of the kicking and crying of the baby, which increases heat production (Schlossmann and Murschhauser). The large differences between the energy-quotients obtained by Heubner and by Czerny-Keller show that the Heubner school dealt with livelier babies than the Czerny school (Talbot). Finally, after 18 hours fasting in a calorimeter, Schlossmann found acetone appears in the urine (Schlossmann and Murschhauser), suggesting that the baby may have passed from a normal to a pathological condition, beyond which point basal metabolism cannot be computed. In applying the principles of metabolism to infant nutrition, the advocates of a single isolated hypothesis, in comparison with the resourceful therapists, become as Emerson's "monotones, the men of one idea." Jacobi has shown that a marasmic infant, fed up to normal and beyond it by a monotone of *Eiweissmilch*, ultimately developed scurvy, to be relieved again by a more varied diet. Thus to indulge the "vanity of dogmatizing" in the matter of infant metabolism is to join the ranks of those who, in the expression of Harvey Cushing "are today, but may not be tomorrow."*

SCIENTIFIC INVESTIGATION OF INFANT METABOLISM AND INFANT NUTRITION

William **Camerer** (1842–1910) of Urach (Württemberg), a Tübingen medical graduate (1866), served as a medical officer in the Austro-Prussian and Franco-Prussian wars (1866–70), and later specialized in metabolic disorders in his private clinic. He published monographs on obesity (1886), diathetic disorders (1888) and an important treatise on the metabolism and energy requirements of childhood from birth to full growth (1894, 2d. ed., 1896), based upon his own close observations. This won the Stiebel Prize (1898) and was followed by his studies (with Söldner) of the composition of human milk (1895–1903) and of changes of weight in 283 infants in the first year of life.

Johann Otto Leonhardt **Heubner** (1843–), a pupil of Widerhofer (Vienna) and an assistant of Wunderlich (Leipzig), graduated at Leipzig (1867), served as a medical officer in the Franco-Prussian war, and became professor extraordinarius of internal medicine at Leipzig (1873) and director of the University Polyclinic (1876). In 1891, he secured the erection of a children's hospital at Leipzig and became the first professor of pediatrics in the University. In 1894, he succeeded Henoch at Berlin, the first full professorship in Germany, with the directorship of the Pediatric Clinic and Polyclinic at the Charité. He published contributions to internal military medicine (1871), an epoch making study of syphilis of the cerebral arteries (1874), the articles on syphilis oft he brain and cord and dysentery in Ziemmsen's *Handbuch* (1873–74), a prize essay on experimental diphtheria (1883), essays on cerebral meningitis (1886), scarlatinal diphtheria (1888), infant nutrition and children's hospitals (1879), chronic nephritis and albuminuria in children (1891), treatment of disorders of infant nutrition (1894), syphilis in children (1896), the metabolism of a boy (1902) a splendid treatise on pediatrics, based upon his own clinical findings, (1903–6, 3. ed., 1911), a valuable history of the pediatrics of infancy (1909) and a volume of pediatric essays (1912). In 1894, Heubner built, with his own hands, the first successful respiration calorimeter. In 1898–9, appeared the classic monographs of Max Rubner and Heubner on the average daily food (energy) requirements of the normal and atrophic infant,* which have remained the basis of all subsequent metabolism experiments on infant feeding. He inaugurated the method of caloric feeding. In 1901 he introduced the concept of the "energy quotient,"† *i.e.*, the number of large calories per kilogram of body weight *per diem* necessary for infant growth. In 1911, he introduced his theory of "digestion insufficiency." He made Barlow's disease known in Germany. Heubner is a distinct leader of modern

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* If the above expression of opinion seems exaggerated, let me call attention to Schlossmann's address of 1908 (Deutsche med. Wochenschrift, 1908, xxxiv, (1713–1715), in which he says that "Investigations in infant nutrition are legion, but the master word, fusing all into a harmonious whole, remains yet to be spoken." Schlossmann cites the utterances of Goethe ("Investigations of the first order are all the more valuable, because incomplete, just as those of a lesser order are always completed"); and of Liebig ("Modern physiology lacks a great centric idea to which all investigations must inevitably converge; hence the perpetration of some colossal error in this science would be a positive advantage"). Equally apposite is Lord Bacon's dictum "It is easier to evolve truth from error than from confusion."

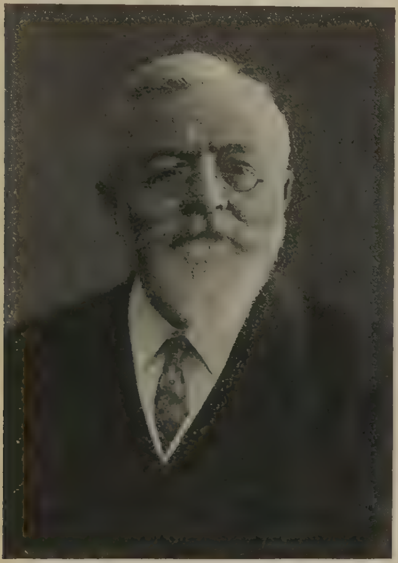

FIG. 36.—Johann Otto Leonhardt Heubner (1843–). (Courtesy of Dr. J. H. Hess, Chicago.)

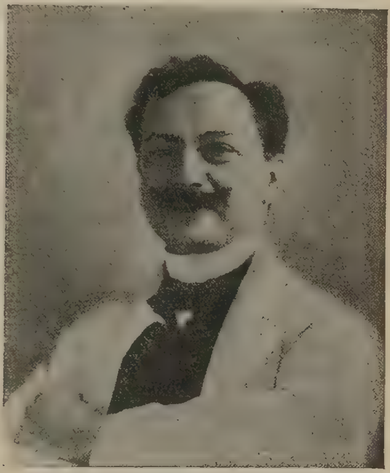

FIG. 37.—Adalbert Czerny (1863–). (Courtesy of Dr. Henry F. Helmholz, Chicago.)

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* Rubner and Heubner, Ztschr. f. Biol., Munich, xxxvi (1898), p. 1; xxxviii (1899), p. 315.

† Heubner, Ztschr. f. diät. u. phys. Therap., Leipzig, v (1901–2), pp. 13–35.

pediatric thought and an influential teacher, numbering among his pupils Finkelstein, Langstein, Stoeltzner and Salge. Heubner is described by Finkelstein as "nothing of the pompous, prepense Olympian of calculated sublimity and pathetic stage gestures, but a genuine, whole-hearted human man, full of life, movement, fire, natural, original and impulsive in every fibre of his being." In old age, he was not "the ossified, myopic discourager of youth," but carried the younger men along with him by the youthful freshness and charm of his own personality.

Adalbert **Czerny** (1863–), of Szczakowa, Galicia, a pupil of Epstein, graduated M.D. at Prague (1888), and succeeded Soltmann as professor extraordinarius at Breslau (1894), where he founded a Pediatric Clinic and Polyclinic. In 1906, he became full professor, and in 1910, professor at Strassburg, and succeeded Heubner in Berlin in 1913. He published a histological study of degenerative processes in the liver (1890), lectures on the physician as educator of the child (1908, 3. ed., 1911) and with A. Keller, a great treatise on the nutrition and nutritive disorders of childhood and their treatment (1906).* In 1893, he studied the duration of gastric digestion. In 1906, he studied, with Keller, the change in the composition of maternal milk when the breasts are not emptied, the harmfulness of fat and the provenance of fecal fat, and made, with Steinitz, a collective investigation of the nitrogen metabolism of infants. In 1906–8, he introduced his concept of an "exudative diathesis" and the exanthems produced by ingestion of fat in this condition, which was confirmed experimentally by Steinitz and Weigert in 1910. Czerny also introduced the idea of long pauses in feeding the baby, and has created an individual school of pediatric thought by leading physicians away from exclusive contemplation of the infantile intestine and its contents to the intermediary processes of metabolism.

Heinrich **Finkelstein** (1865–), of Leipzig, graduated in philosophy (1888) and medicine (1893) at Berlin, became assistant at the pediatric clinic in the Charité (1894), and is now professor in the University (1913), and is head physician to the Orphan Asylum and the Children's Asylum. In 1902, he published an essay on infantile diseases due to trauma, in 1904, with L. Ballin, a monograph on the nursling-foundlings of Berlin and their institutional care, in 1905–12 a two-volume treatise on diseases of nurslings, in 1906–10, a series of papers setting forth his theory of sugar and salt intoxication (alimentary fever)† with the introduction of albumin milk (*Eiweissmilch*), a mode of starvation feeding, which is employed until the intestinal disorder is relieved. Finkelstein's initial theory that sugars are harmful (1906) has been modified by him to the effect that fat is only harmful when the intestines are irritated by carbohydrate fermentation (1910). In 1911, appeared his *Arbeiten* from the Berlin Children's Asylum. Finkelstein, a man of broad philosophical education, is described as a keen, close observer and most remarkable clinician of the analytic type. Like several other eminent physicians, he early made his mark in geology (Abt).

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* Czerny and Keller, "Des Kindes Ernährung, Ernährungsstörungen und Ernährungstherapie." Leipzig and Wien (1906).

† Finkelstein, Verhandl. d. Gesellsch. f. Kinderheilk., Stuttgart, xxiii (1906), p. 117. Jahrb. f. Kinderheilk., lxv (1907), pp. 1, 263; lxviii (1908), p. 521; lxxi, (1910), p. 525.

Arthur **Schlossmann** (1867–), of Dresden, who was simultaneously director of the Pediatric Polyclinic and Infant's Home at Dresden, and, in 1906, became professor and director of the Children's Clinic at Düsseldorf, has written on rickets (1891), diphtheria (1894), the differences between human and cow's milk (1898), and the composition of human milk (1900–1902), poisons and tuberculosis (1906), the care of infants in the first two years of life (1907), and stall hygiene (1909). He did most for the organization of infant hygiene on a grand scale. In 1908, he showed that the saliva of the newborn converts starch into sugar as soon as secreted. With H. Murschhauser, he showed the marked influence of muscular activity on heat production in the attempt to ascertain the basal metabolism of the infant (1908–14);* and investigated the fasting metabolism of infants, showing the pathological appearance of acetone in the urine, after 18 hours fast, from the privation of food carbohydrates (1913). He collaborated with M. von Pfaundler in a pediatric *Handbuch*, on the co-operative plan

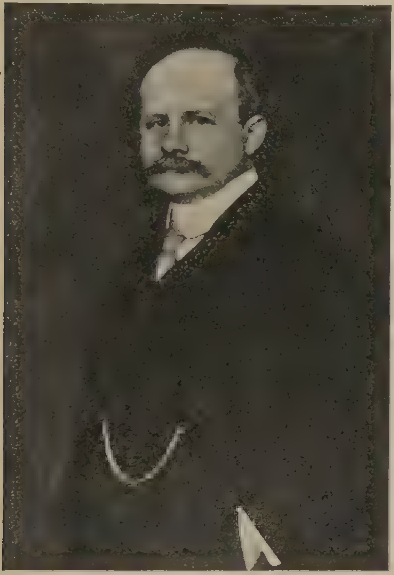

Fig. 38.—Heinrich Finkelstein (1865–). (Courtesy of Dr. Isaac A. Abt, Chicago.)

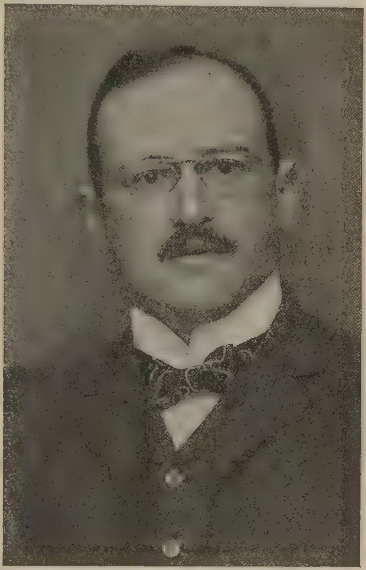

Fig. 39.—Arthur Schlossmann (1867–). (Courtesy of Dr. J. H. Hess, Chicago.)

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* Schlossmann and Murschhauser, Biochem. Ztschr., Berlin, xiv (1908), p. 369; xxvi (1910), p. 14; liii (1913), p. 265; lvi, p. 355; lviii (1914), p. 483.

(1906, 2d ed., 1910–12), which was translated into English under the editorship of Henry L. K. Shaw and Linnaeus E. La Fetra (1908, 2. ed., 1912). Schlossmann is co-editor of the *Archiv für Kinderheilkunde* (1902), and the *Zeitschrift für Säuglingsfürsorge* (1910).

Meinhard von **Pfaundler** (1872–) director of the University Pediatric Clinic at Munich, investigated the anatomy of the suprarenal glands (1892), the gastric capacity of infancy and childhood (1898), spinal puncture in children (1899), calcium absorption in rickets (1904,) and, with E. Moro, demonstrated that hemolysin is a normal constituent of different milks (1907.) He collaborated with Schlossmann in the above-mentioned *Handbuch der Kinderkrankheiten* (1906). His pediatric clinic at Munich is one of the best on the continent.

FIG. 40.—Meinhard von Pfaundler (1872–). (Courtesy of Dr. J. H. Hess, Chicago.)

Arthur **Keller** (1868–), Czerny's assistant, has written on the care of illegitimate infants (with H. Reicher, 1909), infant nutrition (1901), infant welfare and child-protection in England, Scotland and Hungary (1911) and collaborated with Czerny in his massive treatise on infant nutrition (1906). He showed that breast-fed infants retain more (or excrete less) phosphorus than the bottle-fed, which was confirmed by L. F. Meyer (1908) and by Knox and Tracy (1914). He also showed that carbohydrates make protein digestion more complete. In 1912, he edited (with Chr. J. Klumker), a collaborative history of infant welfare and child-protection in Europe by many hands.

Leo **Langstein,** private-docent in pediatrics at the University of Berlin, graduated at Leipzig with a dissertation on albuminuria in older children (1897) and collaborated with L. F. Meyer in a sterling work on infant nutrition and metabolism (1910),* the clearest, most compact and most intelligible of all modern books on this subject. He investigated erepsin in the fetus (with Soldin, 1908) and showed (with Steinitz) the presence of lactose in all stools of enteritis (1909).

Ludwig F. **Meyer,** Finkelstein's pupil and privat-docent at Berlin, collaborated with Langstein in the above mentioned work on infant nutrition (1910), showed the retention of nitrogen for tissue-building in fasting infants and as the amount of protein in food is increased

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* Langstein and Mayer, "Säuglingsernährung und Säuglingsstoffwechsel." Wiesbaden (1910).

(1908), investigated infantile atrophy under different conditions and with different foods (1910) and showed that normal babies are able to digest fats, since there is no loss of fat or salts when fats in the food are increased (1910). Langstein and Meyer also did important work on alcaptonuria and the effect of sugar on infant nutrition.

Hermann **Brüning** (1874–), professor extraordinarius of pediatrics at Rostock, where he habilitated with a dissertation on infant nutrition (1906), is the author of a history of artificial nutrition of infants (1908), a study of infant mortality in Mecklenburg-Schwerin (1909), and edited with E. Schwalbe, a collaborative Handbook of the General Pathology and Pathological Anatomy of Childhood (1912).

Emil **Feer** (1864–), of Aarau, Switzerland, settled as pediatrist in Basel (1892), became professor extraordinarius and director of the Pediatric Clinic at Heidelberg (1907) and later professor of pediatrics and director of the University Pediatric Clinic at Zürich (1911). He wrote on the power of heredity (1905), diseases of the air-passages and respiratory organs in infancy (1906), the influence of consanguinity of the parents on the child (1907). In 1896, he showed that the nursling gets one-half its meal in the first five minutes of suckling and more than one-quarter in the next five minutes. In 1910, he published a concise and comprehensive *Lehrbuch der Kinderheilkunde*, containing contributions on infantile diseases and digestive disorders by Finkelstein, blood and diathetic diseases by Pfaundler, diseases of the air-passages and tuberculosis by Pirquet, diseases of the heart and infectious diseases by Feer, diseases of the genito-urinary organs by Tobler, diseases of the nervous system by Ibrahim, syphilis and cutaneous diseases by Moro. This became so popular that it reached its third edition in 1914.

Ludwig **Tobler** (1877–1915) of Zürich, graduated at Zürich (1902), became assistant in the pediatric clinic (1905) and professor extraordinarius (1911) at Heidelberg and later professor and director of the University Clinic at Breslau (1911). He investigated the axillary arch in man as a vestige of the mammalian panniculus carnosus (1902), studied the mechanism of gastric digestion (1905–6), the coagulation-time for casein in the stomach (1906), the duration of gastric digestion in infancy, using the *X*-ray (1908), and showed that fats delay the emptying of the stomach and that large amounts of fats cause pyloric spasm (1907). With Noll, he studied the calcium metabolism in infants (1910) and collaborated with Bessau in a work on the pathological physiology of nutrition and metabolism in children (1914).*

Yussuf **Ibrahim,** director of the Hamidié Hospital, founded by Sultan Abdul Hamid II at Constantinople in 1898, and latterly of the Gisela Children's Hospital at Munich, habilitated at Heidelberg with a dissertation on congenital stenosis (1905), wrote on rheumatism (1906) and nervous diseases (1911) in children, and in 1908 made an important contribution on the digestive ferments in the stomach, pancreas and intestines of the newborn infant.* He was the first to find enterokinase in the intestinal mucous membrane of the newborn (1908).

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* Tobler and Bessau, "Allgemeine pathologische Physiologie der Ernährung und des Stoffwechsels im Kindesalter." Wiesbaden (1914).

Franz von **Soxhlet** (1848–1907), of Brünn, Moravia, professor of agricultural chemistry in the Technical High-School at Munich, has written on the physical chemistry of milk (1872), the nature of milk droplets (1876), metabolism of the calf (1878), fat formation from carbohydrates (1882), the chemical differences between human and cow's milk (1893) and devised a method for estimating the fat-content of milk (1881) and the well-known method and apparatus for sterilizing infant's milk (1886).† Other valuable studies of milk have been made by C. O. Jensen (1903), Milton J. Rosenau (1908–12), K. Winslow (1909), Paul Sommerfeld (*Handbuch der Milchkunde*, 1909) and Janet E. Lane-Claypon (1912–13).

In France, Pierre-Constant **Budin** (1846–1907), of Paris, who succeeded Tarnier as professor of obstetrics on the Paris Faculty (1898), has written on the sterilization of milk (1892), on lying-in women and the newborn infant (1897), a *Manual pratique de l'allaitement* (1905, 2. ed., 1907), and a comprehensive treatise on the nursling (*Le Nourrisson*, 1900), which has been translated into English (1907), and is frequently drawn upon as a storehouse of interesting facts.

Henri de **Rothschild** (1872–), head physician of the Polyclinic H. de Rothschild and director of the *Revue d'hygiène et de pathologie infantile* (1902), has written on sterilized milk in infant nutrition (1897), the hygiene and protection of childhood in Europe (1897), gastro-intestinal troubles in infancy (1898, 1904), *L'allaitement mixte et l'allaitement artificial* (1898), the hygiene of milk feeding (1899), the milk-industry (1903–4), has prepared an exhaustive and valuable bibliography of milk (*Bibliotheca lactaria*, 1901–2), and has edited a massive and sumptuous treatise on the hygiene and pathology of infancy, by various authors (1905). Rothschild is a sportsman, playwright and philanthropist-physician, whose activities in securing milk-depots for the poor of Paris are comparable with those of Nathan Straus in New York (1890). He was one of the first to found a "Nursling's Consultation" or "Mother's Home" in Paris, which soon outgrew its modest home in the rue Picpus and, in December, 1902, acquired a splendid building in the rue Mercadet. In 1905 a brilliant banquet was given in his honor, at which his former teachers, Dieulafoy, Budin, Poirier, responded in terms of cordial praise.‡

Luigi **Concetti** (1854–1920), of Rome, a very active teacher, wrote much on pediatric instruction (1895–1911), and a treatise on infant hygiene (1903). Francesco **Fede** (1832–1913), editor of *La Pediatria* (1893), described the sublingual tumor (*produzione sottolinguale*) to which Riga of Naples drew attention in 1881 (Riga's disease).

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* Ibrahim, Verhandl. d. Versamml. d. Gesellsch. f. Kinderheilk., deutsch. Naturf. u. Aerzte (1908), Wiesbaden, xxv (1909), pp. 21–42.

† Soxhlet: München med. Wochenschr., xxxiii (1886), pp. 253, 276.

‡ Hommage au Dr. Henri de Rothschild. Progrès méd., Paris, xxi (1905), 3. s., pp. 371–376.

In Russia, much work has been done on the physiology of infantile digestion in "The Peculiarities of Childhood" by N. P. **Gundobin** (1912) and the papers and students' theses of Glinsky (1895), Sotoff (1895), Wulfson (1898), Geptner (1900), Harge (1900) Debele (1901), Kovalski (1900), Snarsky (1901), Borisoff (1903), Heymann (1904), Sellheim (1904), and others (Morse and Talbot).

Thomas Morgan **Rotch** (1849–1914), of Philadelphia, a medical graduate of Harvard (1874), eventually held the first professorship of pediatrics in that University (1888). He did much to give pediatrics a definite place in the medical curriculum, established the Infant's Hospital and the first milk laboratory (Walker-Gordon, 1891) in Boston, wrote an important pediatric treatise (1896) and was the pioneer of the clean milk idea in America. His Walker-Gordon laboratory was soon followed by similar aseptic establishments in London and elsewhere. He introduced the method of percentage or substitute feeding of infants (1896) in which fats, carbohydrates and sugar were given in dosage approximate to the needs of different babies. The doctrine of proteins, upon which the advocates of percentage feeding relied, was contravened by the purposeful *Eiweissmilch* of Finkelstein, which (as although nearly free from lactose) was again evolved from the equally dubious doctrine of the indigestibility of sugars. Rotch also did some important work on pericarditis and pericardial punctures; and, toward the end of his life, made some researches on the physiological age of children, using *X*-ray pictures of the small bones of the wrist as a basis for an anatomical index of growth in relation to the "somatic" as opposed to the "chronological" age of the child (1907–10).*

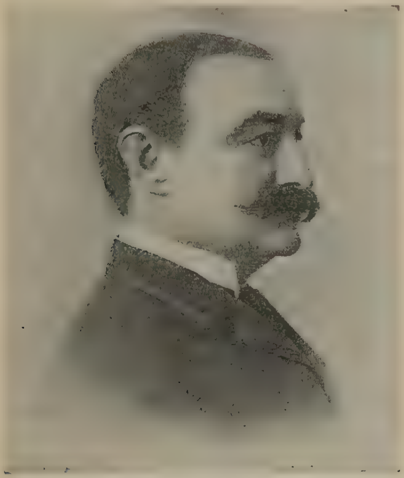

FIG. 41.—Thomas Morgan Rotch (1849–1914).

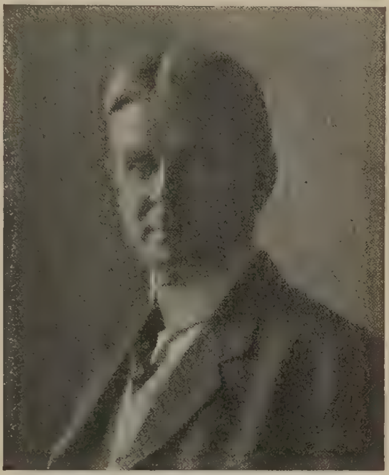

FIG. 42.—Luther Emmet Holt (1855–).

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* For a good account of Rotch's work, see A. Jacobi, Am. Jour. Dis. Child., Chicago, viii (1914), pp. 245–249.

Luther Emmet **Holt** (1855), of Webster, N. Y., a graduate of the College of Physicians and Surgeons, New York, and professor of diseases of children in the New York Polyclinic (1890) and the College of Physicians and Surgeons (1902), is an acknowledged leader of pediatrics in this country, a strong executive and an able teacher and writer. He is the author of treatises on the Care and Feeding of Children (1894, 8th ed., 1915) and the Diseases of Infancy and Childhood (1896, 7th ed., 1916) and a large number of minor contributions. He has been a principal advocate of home modifications of milk and pasteurized milk. In the laboratory study of infant metabolism, he has worked with P. A. Levene, Angela M. Courtney, D. D. Van Slyke and Helen L. Fales on the effect of high protein feeding (1912), casein feeding (1913), the chemical composition of diarrheal stools (1915), the excretion of magnesium sulphate (1915), human milk (1915) cod-liver oil in infantilism (1917) and fatty metabolism in infants (1919). Holt has also written a suggestive historical study of infant mortality (1913), and, with Miss Ellen C. Babbitt, a valuable statistical analysis of institutional mortality in the new-born, based upon 10,000 consecutive births(1915).

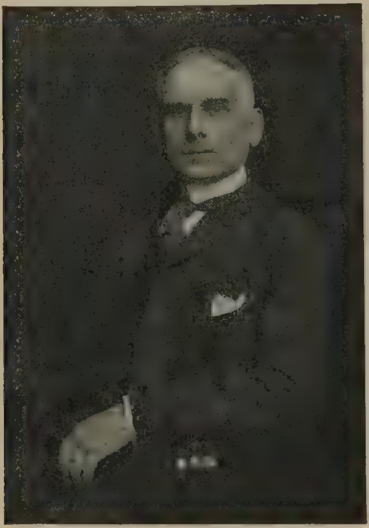

Fig. 43.—Henry Dwight Chapin (1857–).

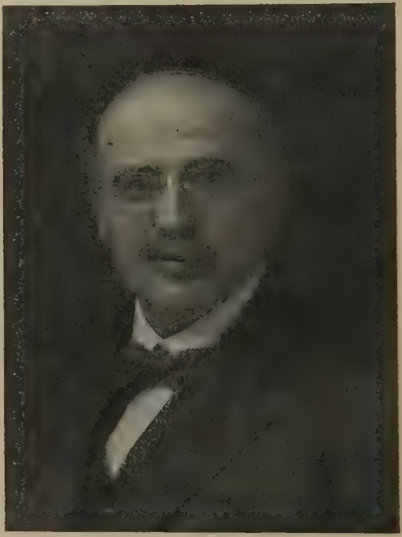

Fig. 44.—Isaac Arthur Abt (1867–).

Henry Leber **Coit** (1854–1917), of Peapack, New Jersey, a graduate of the College of Physicians and Surgeons, New York (1883), was the originator of the certified milk movement in the United States, which he worked out in a dairy plant near Newark in the first instance. He also organized an infant's hospital at Newark.

Henry Dwight **Chapin** (1857–), of Steubenville, Ohio, a graduate of the College of Physicians and Surgeons, New York (1881), professor of pediatrics in the New York Post Graduate Medical School and Hospital, was, with Jacobi, the principal advocate of standardized cereal gruels in infant feeding. He has studied the biological aspects of different milks, invented the Chapin milk-dipper, and is the author of a "Theory and Practice of Infant Feeding" (1902, 3d ed., 1909), Vital Questions (1909), and, with Godfrey Roger **Pisek** (1875–1921), of New York, a Treatise on Diseases of Children (1909, 4th ed., 1919). He has also written on the function of maternal milk in developing the stomach (1903), proteid incapacity in infant and child (1907), acidosis of intestinal origin (1916) and established the distinction between the gross caloric value of a food and its net caloric value, *i.e.*, the energy required for its digestion and assimilation (1913). Chapin has done much in humanitarium work for the homeless infants of the poor in New York City.

Isaac Arthur **Abt** (1867–), of Wilmington, Illinois, a graduate of the Johns Hopkins University (1889) and of the Chicago Medical College, Chicago (1891), was interne of Michael Reese Hospital (1891–3), did post-graduate work in Vienna and Berlin (1893–94), and has been professor of pediatrics in the Northwestern University, Woman's Medical School (1909), Rush Medical College and the Michael Reese, Cook County and other Chicago hospitals. As the leading pediatrist in the West, he is widely known as a teacher, writer and editor. He is the author of "The Baby's Food" (1917), and editor of the pediatric volumes in the Practical Medicine Series (1906–21).

He has made a large number of investigations, notably of floating kidneys in children (1901), acute non-suppurative encephalitis (1906), rachitic erosions of permanent teeth as a result of infantile diseases (with Mortimer Frank, 1908), status of the kindergarten (1908), irritating effects of cathartic drugs in infants (1909), traumatic diabetes (1911), "starch-injuries" (1913), unusual types of acid intoxication (1914), 226 cases of chorea (1916), familial icterus in newborn infants (1916). He has also written an interesting history of the classification of gastro-intestinal diseases (1912).

John **Howland** (1873–), of New York, a graduate of University Medical College, New York (1897), and professor of pediatrics in the Medical Schools of Washington University, St. Louis, (1911) and the Johns Hopkins University (1912), has been a pioneer in American work on the fundamental requirements of infant nutrition. In 1910–11, he studied the chemical and energy metabolism of sleeping children, substituting direct calorimetry for computations from heat-measurement, and in 1913, he devised a formula for estimating the area of body surface in connection with infant metabolism. He assisted Holt in the sixth and seventh editions of his pediatric treatise (1911, 1919,) and with his talented associate, William McKim **Marriott** (1885–), has made important studies on acidosis and acetone-body production in children's diseases (1916) and the calcium content of the blood in rachitis and tetany (1916). Marriott has devised methods for determining the alkali content of the blood plasm (1916) and the alveolar carbon dioxide (1916).

John Lovett **Morse** (1865–), of Taunton, Mass., a graduate of

Harvard (1887), and of Harvard Medical School (1891), practised in Boston (1892) and became instructor in pediatrics in Harvard Medical School (1903–6), assistant professor (1906–15) and professor (1915). An unsurpassed clinician, he has written a great number of papers from his large experience, culminating in his Case Histories in Pediatrics (1911, 2d ed., 1913), in which the subject is taught inductively by the synthetic method. He is also the author of the Care and Feeding of Children (1914), and of studies on the overheating of food as a cause of scurvy (1906–14) and on casein dyspepsia (1913); and has collaborated with Fritz Talbot in the Diseases of Nutrition and Infant Feeding (1915, 2d ed., 1920), a book in which the history of the subject is deftly interwoven, with valuable footnotes, as in Schaefer's Physiology.

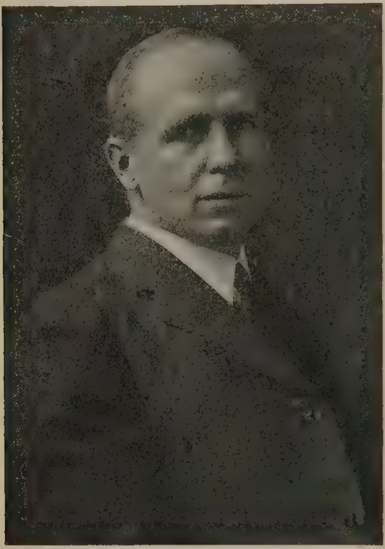

FIG. 45.—John Howland (1873–).

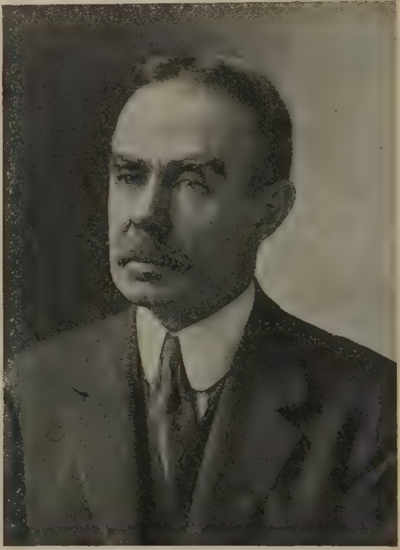

FIG. 46.—John Lovett Morse (1865–).

Fritz Bradley **Talbot** (1878–), of Boston, a graduate of Harvard (1900) and Harvard Medical School (1905), after clinical experience in the Children's Hospital, Boston (1905) and the Massachusetts General Hospital (1905–7), was Morse's assistant for three years, at the same time doing work in biological chemistry at Harvard. He is now instructor in pediatrics in the Harvard Medical School, was visiting physician to the Boston Floating Hospital (1909–14) and since 1909 has been chief of the Children's Medical Department at the Massachusetts General Hospital. Well-grounded in the best type of American training, Talbot has attacked some difficult problems. In 1909–10, he investigated the large and small curds in infants' stools, showing, by serologic methods, that the large bean shaped curds, originally examined by Biedert (1888), are composed of casein, the small soft curds, examined by Uffelmann (1881), Fr. Müller (1884), Escherich (1888), being made of fatty acids or soaps. In 1912, he began his studies on the gaseous interchange and general metabolism of infants with Francis Gano **Benedict** (1870–), of Milwaukee, director of the Nutrition Laboratory of the Carnegie Institution of Washington, resulting in two monographs on the Gaseous Metabolism of Infants (1914) and the Physiology of the New-born Infant (1915). Talbot has also investigated the effect of lactose on nitrogen metabolism (with L. Hill, 1914), the energy metabolism of the decerebrate infant (1915) and the cretin (1916–18), the protein metabolism of infants (with J. L. Gamble, 1916), and the relation of asthma in children to anaphylaxis (1914–16). He collaborated with Morse in the book on infant nutrition above mentioned (1915, 2d ed., 1920).

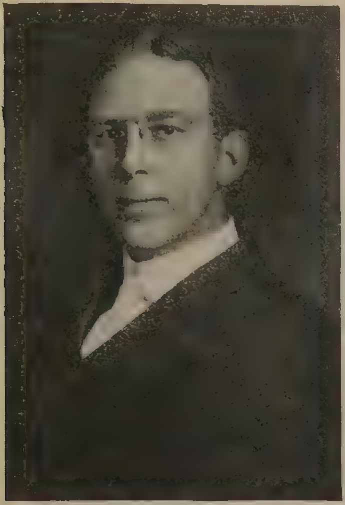

Fig. 47.—Fritz Bradley Talbot (1878–).

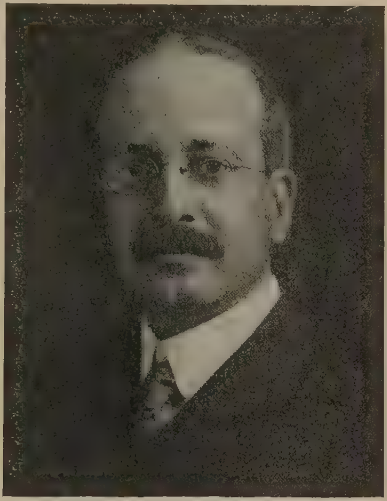

Fig. 48.—John Ruhräh (1872–).

John **Ruhräh** (1872–), of Chillicothe, Ohio, a graduate of the College of Physicians and Surgeons (Baltimore, 1894), did post-graduate work at the Johns Hopkins, the Pasteur Institute, Paris (1897) and in other European schools (1900–1901), was quarantine physician of the port of Baltimore (1898–1900), where he is now professor of pediatrics in the University of Maryland Medical School and in the College of Physicians and Surgeons. He made the first collective investigation of actinomycosis in the United States (1899–1900), introduced the soy bean in infant dietetics (1909), and is the author of a useful manual of the Diseases of Infants and Children (1905, 4th ed., 1914) with Julius Friedenwald, Diet in Health and Disease (1905, 5th ed., 1919) and Dietetics for Nurses (1905, 4th ed., 1917) and, with Erwin F. Mayer, a treatise on "Poliomyelitis in all its aspects" (1917). He has been active in medical library work, was instrumental in the erection of the new Library building of the Medical and Chirurgical Faculty of Maryland and is editor of the *Bulletin of the* Medical Library Association (1911).

Bert Raymond **Hoobler** (1872–), professor of pediatrics in the Detroit College of Medicine and Surgery, has done important work on the retention of mineral salts in infant metabolism (1911), the effect of protein diet on the product of human milk (1917), and is the deviser of an adjustable metabolism bed (1912) and a device for standardizing blood-pressure readings (1912). He also investigated the metabolism of ten hospital infants and devised a respiration incubator for the energy metabolism of infants (1915) with John R. **Murlin** (1874–), who has also studied the metabolism of development (1910) and the metabolism of mother and child just before and after birth (with Carpenter, 1911).

Alfred Fabian **Hess** (1875–), clinical professor of pediatrics in the University and Bellevue Hospital Medical College, devised a duodenal tube and catheter (1911–12) and investigated infantile jaundice (1912), allergy to common foods (1912), the leucocyte count in pneumonia and meningitis (1914), pylorospasm and allied spasm (1914), gastric exploration (1914–15), protective therapy for mumps (1915) and has recently made extended studies of infantile scurvy (1916–19), summarized in his treatise of 1920.

Julius Hays **Hess** (1876–), professor of pediatrics in the College of Medicine, University of Illinois, and chief of the pediatric staff at Cook County Hospital (Chicago) is the author of recent books on infant feeding (1918, 2nd ed. 1919) and on premature and congenitally diseased infants (1921).

Of other work in this field, it is sufficient to mention that done in the Russell Sage Institute of Pathology by Graham Lusk, Eugene F. Dubois, Delafield Dubois and Frank C. Gephart on clinical calorimetry (1915–16), the method of estimating fats devised by Gephart and F. A. Csonka (1914), the linear formula of Delafield Dubois for calculating the surface area of the body (1915), the investigations of E. F. Dubois on metabolism in boy-scouts (1915–16), the survey of Lucy H. Gillett on evidence regarding food allowances for healthy children (1910) and of Gillett and Sherman on Adequacy and Economy of Some City Dietaries (1917).

Bacteriology and Serology

The work of Pasteur, Koch and Lister brought about some striking improvements in practical pediatrics. The studies of the great Viennese pediatrists, Bednar and Ritter von Rittershain, upon the intestinal toxemias and wound-infections of infancy were carried forward into direct prophylaxis by Epstein, who instituted the most rigid aseptic procedure, an absolute surgical cleanliness, in the hygienic management of the wards in foundling asylums and their inmates, lowering the mortality, during 14 years, from 30 to 5 per cent. Prior to this period, Gottfried **Eisenmann** had suggested the instillation of chlorine water to prevent infantile conjunctivitis (1830), which was neglected until the obstetrician, C. S. F. **Credé** (1819–61) introduced his silver nitrate solution (1884). Ignaz Philipp **Semmelweis** (1818–65) made himself immortal by his precautionary measures against puerperal septicemia (1847–61), which was followed by the carbolic acid solution of Étienne **Tarnier** (1881). Pediatrists trained in technical chemistry, like Schlossmann, took up the hygiene of stalls and of milk and the milk-supply, so that infant life was truly surrounded, in hospital at least, by every aseptic precaution. In 1886* Theodor **Escherich** (1857–1911)† of Munich, a pupil of Gerhardt, professor at Graz (1890, 1894) and Vienna (1902), where he succeeded Widerhofer, published the first treatise on the intestinal bacteria of infants, a classic work which is still a monument of research. It was based upon his new method of isolating bacteria in infantile feces (1884). The infant's mouth (sterile at birth) is infected by the bacteria from the mother's vagina during labor, and from the air, nipples, milk and other foods after birth. Escherich described the swarming bacterial flora of the intestines and gave the first account of bacillus coli infection. Other bacteria, such as the Bacillus bifidus of Tissier, the bacillus acidophilus of Moro, the Welch bacillus and the peptonizing bacillus of Rodella have since been found. Noguchi has changed the bacillus bifidus into b. acidophilus and back again (1910), and while it has been difficult to prove pathogenicity of the infantile strains in laboratory cultures, Escherich, in 1900, described an epidemic of severe diarrhea (*blaue Bacillose*) from the normal acidophilic flora of the infantile intestine, which, in the view of Moro (1905), demonstrates the possibility of endogenous infection. In 1900, Escherich advanced the hypothesis that the bacterial changes in the intestine, exogamous or endogamous, may set up a mild intoxication or "chymus infection," an afebrile, acid mucous diarrhea (the ordinary banal gastro-enteritis), which may be followed by a secondary infectious, toxic gastro-enteritis, the equivalent of the various dyspepsias and intestinal catarrhs of the past. In 1889, he tabulated the nutritive requirements of infants by age. In 1902, he maintained that sugar is harmful to the infant as being a culture-medium for the growth of pathogenic bacteria of the intestines.‡ In 1892, Paul **Ehrlich** (1854–1915) showed that immunity is transmitted to the infant through the maternal milk; that artificial immunity can only be acquired through the milk, and that immunity

FIG. 49.—Theodor Escherich (1857–1911). (Courtesy of Dr. J. H. Hess, Chicago.)

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* Escherich, "Die Darmbakterien des Säuglings." Stuttgart (1886).

† For biography of Escherich, see Finkelstein, Deutsche med. Wochenschr., Leipzig and Berlin, xxxvii (1911), p. 604; Pfaundler, München med. Wochenschr., lvii (1911), pp. 521–523; von Pirquet, Ztschr. f. Kinderheilk., Berlin, i (1910–11), pp. 423–441 (with bibliography).

‡ Escherich, Deutsche Klinik, Berlin, vii (1902), p. 126.

may be transmitted by milk of the same species but not by milk of another species. Jules **Bordet,** in 1899, showed that injection of cow's milk into other animals produces a precipitin in the blood for the albuminous bodies of cow's milk, which it coagulates. August von **Wassermann** (1866–) showed that the proteins of different animals are different, *i.e.*, that the blood serum of animals sensitized to cow's, human or other milks will precipitate that particular milk and no other (1900). Clemens von **Pirquet** (1874–), former professor of pediatrics in the Johns Hopkins University and at Breslau (1900), and director of the University Pediatric Clinic at Vienna (1911) introduced the cutaneous reaction to tuberculin (1907), which is of great use in the diagnosis of infantile tuberculosis; developed the doctrine of allergy (1907–11) and "serum disease" (1905–7); and the doctrine of feeding by nems (energy in 1 cc. of milk), estimated by a height: weight ratio, in place of calories (1917). In this connection the formula of George Dreyer for the relation of vital capacity to body weight and surface (1919) is important. Pirquet's assistant, B. Schick, discovered the cutaneous reaction for estimating the extent of antitoxin producing power in the blood (1910). Ernst **Moro** demonstrated the presence of an amylolytic ferment in the pancreas of the newborn (1898), showed the rapid increase in starch-digesting power in the first week of life (1898), showed that the blood of breast-fed infants is more bactericidal than that of the bottle-fed, maintained the doctrine of endogenous infection from the normal bacterial flora of the infantile intestine (1905–7), introduced the skin reaction with tuberculin (1908) and a specific reaction for human and cow's milk (1912).

FIG. 50.—Clemens von Pirquet (1874–).

FIG. 51.—Julius Parker Sedgwick (1876–).

William David **Booker** (1844), of Virginia, clinical professor of pediatrics in the Johns Hopkins University (1897), investigated the bacteriology and pathology of the summer diarrheas of infants in 1888–96.

Oscar Menderson **Schloss** (1882–   ) of Cincinnati, professor of pediatrics in the Medical Department, Harvard University, has done some remarkable work on the relation of the metabolism of nitrogen, phosphorus and the purin substances to uric acid infarcts in the kidney (1911–16), on protein sensitization to eggs and other food products (1915), and the permeability of the gastro-enteric tract of infants to undigested protein (1916). Julius Parker **Sedgwick** (1876–   ), of Wrightstown, Wisconsin, a graduate of Rush Medical College, Chicago (1899) and, professor of pediatrics in the University of Minnesota (Minneapolis) discovered a fat-splitting ferment in the stomach contents of the newborn infant (1906),* has investigated recurrent vomiting (1912), spasmophilia in children (1912–16), oxalic acid excretion in the urine of children (1915), the uric acid content of the blood in the newborn (1917) and has shown (with W. P. Larson) that the complement-fixation test with the bacillus abortus is present in the blood of women who have aborted and in the blood of many children (1913–15).† William Palmer **Lucas** (1882–   ), professor of pediatrics in the University of California Medical School, San Francisco, has studied the cytology of meningitis (1911), rheumatic endocarditis in infants (1914), the blood picture in the diagnosis of measles (1914) and has made a special study of the delinquent child. David Murray **Cowie** (1872–   ), professor of pediatrics in the University of Michigan Medical School (Ann Arbor) has studied the serum disease (1914) and the intradermal reaction to diphtheritic antitoxin (1916); and Borden Smith **Veeder** (1883–   ), associate professor of pediatrics in the Washington University Medical School (St. Louis) has investigated the metabolism of infants (with C. A. Fife, 1911), the bacteriology of the intestinal diseases of infancy (1912) and, with M. R. Johnston, the frequency of infection with the tubercle bacillus (1915), the chemistry of urine (1916) and the creatin and creatinin content of the blood (1916).

Kenneth Daniel **Blackfan** (1883–   ) has investigated the skin reaction from proteins in eczema (1916), and, with Walter E. Dandy, the pathology of internal hydrocephalus (1914–17). Mathias **Nicoll,** Jr., professor of infectious diseases in the University and Bellevue Hospital Medical College, New York, has done good work on scarlatina (1911) and poliomyelitis (1917) in children, and (with Josephine Pratt) on the infectivity of the bacillus abortus in man (1915).‡ Henry Fred **Helmholz** (1882–   ) pediatrician at the Mayo Foundation, Rochester, Minnesota, has investigated hippuric acid in infants' urine (with S. Amberg, 1913) the infectious nature of duodenal ulcer (with L. Gerdine, 1915) and the bacteriology of the urine (with C. Beeler, 1916). In Jacobi's clinic in the German

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* Sedgwick, Jahrb. f. Kinderheilk., lxiv (1906), p. 194. Arch. Pediat., xxiii (1906), pp. 414–425.

† Larson and Sedgwick, Am. Jour. Dis. Child., Chicago, vi (1913), p. 326; x (1915), p. 197.

‡ Nicoll and Pratt. *Ibid.*, x (1915), 203–205.

Hospital, New York, an auto-serum treatment for chorea has been tried out by Abraham L. Goodman (1916).

INFANT MORTALITY AND INFANT WELFARE

> "De tout temps, l'absence de la mère et la privation du sein et des soins maternels ont été le grand danger et la principale cause de la mort de l'enfant au berceau." Théophile Roussel.

Toward the end of the eighteenth century, the subject of infant mortality and its causes, shamefully neglected in preceding ages, began to engage the attention of observing physicians. In a Swedish royal decree of 1748, the attention of the state authorities is directed to the high infant mortality existing in Stockholm and elsewhere, and one of the causes assigned for it is the lack of proper medical care of the poor.* In 1773, we find a dissertation of Verardo Zeviani, at Verona, *Delle numerose morte dei bambini.* An inquiry into the causes and the best preventive measures, by J. Ballexserd, of Geneva, follows in 1775. This is translated into German (1776), and followed by eight contributions of other writers (in Meissner's lists). In the early nineteenth century, we find Meyer Abrahamson (1806), John Clarke (1815), John Bunnell Davis (1817), John Robertson (1827), Wilhelm Rau (1836), Oertel (1838), and many others writing upon this theme. In his Commentaries (1815), John Clarke judges of infant mortality from the burial records:

> "Nearly a fourth die under two years of age, and, of the survivors, about a fifth in the succeeding eight years, that is under ten years of age . . . More than a third of all the burials are of children under two years of age."

These are generalizations from the older "bills of mortality" established by Henry VIII (1538). The appalling rates of infant mortality in eighteenth century England, Ireland and France have already been given. Underwood saw clearly that "The destruction of infants is eventually the destruction of adults, of population, wealth and everything that can prove useful to society or add to the grandeur of a kingdom." Queen Anne lost all her eighteen or nineteen children, and Gibbon, the sole survivor of seven children, regarded the death of a newborn child as, "an unnatural, but strictly a probable event" (Holt). The mathematician D'Alembert lived to disown his unnatural mother, who had abandoned him in the streets, and to tell her that the poor glazer's wife, who had brought him up to manhood, was his real mother. In the "Cursory Inquiry" (1817) of John Bunnell **Davis,** whom Holt regards as the most prominent pioneer in keen thought upon infant mortality,† the conditions associated with mercenary wet-nursing are clearly recognized as the cause of most infants' deaths, maternal nursing as their best safeguard. Davis founded the only English public dispensary for children in his day, and had a remarkable prevision of modern social service in his idea of visitations by benevolent ladies among the poor for the purpose of looking after sick children and instructing ignorant mothers in the art of properly caring for their infants. Prior to Davis, Richard Watt (1813) investigated the relative mortality from children's diseases in 1783–1812, and concluded that "more than half of the human species died before they were ten years of age and of this half more than a third died of smallpox," which he assumed to be replaced by measles and other infections.* Although the introduction of vaccination brought about some temporary lowering of infant mortality in the Napoleonic period, this good result was soon nullified by certain realignments in the modern social order of things. The French and American Revolutions brought on social democracy and industrialism. The vast improvements in mechanical arts and machinery, with the rapid movement of the rural population to cities as a consequence, created a huge manufacturing class, which was in turn absorbed by a grasping capitalistic régime with a numerous industrial proletariat as its vassals. The skilled artisan of the past was ruined by the large manufacturer, who, later on, was destined to be devoured by the capitalist. The need for cheap labor brought thousands of women into workshops and other fields of activity. As a reaction from the misery and ennui of lonely life on the farm or in the squalor of slums and tenements, and in consequence of the increased cost of living in cities, there was a great increase of prostitution and, therefore, of venereal disease. These factors influenced infant mortality in three ways: 1. Work away from home in factories caused mothers to neglect their children, who were thus exposed to the dangers of hand-feeding or of mercenary wet-nursing. 2. Factory life, under unsanitary conditions, told severely upon the health of the mother and consequently upon the child. 3. Exposure to venereal infection either destroyed the child itself or ruined its health at the start. In William Farr's data of infant mortality in 1860–61 cited by Holt,† the number of deaths per 1000 registered births was: Sweden, 141; Scotland, 149; England, 170; France, 223. In other words, infant mortality was lowest in the cold, bracing climates of Scotland and Sweden, where poverty and a hardy mode of life made it natural and necessary for mothers to nurse their own children; higher in England, where manufacturing interests brought about hand-feeding; highest in France, where the evils of mercenary wet-nursing and baby-farming were everywhere rampant. "In one province of Finland, where the mortality was excessive, investigation showed a great lack of maternal nursing" (Holt). Wartime statistics show that when women lose employment through depression of business, the infant mortality rate inevitably falls, even though the general death rate (as during the siege of Paris) is doubled, for the simple reason that mothers out of employment are driven back to breast feeding because they cannot afford to purchase milk for hand feeding. Holt emphasizes the benign effect of the sheer cheapness of breast feeding in this relation and among the poorer classes generally. In the present European war, increased employment of women in the munition factories increased the rate of infant mortality in France (Budin), but not in England. In 1859–61, Sir John Simon and others showed that the infant mortality curve rises in direct proportion to the extent of maternal employment. As shown in Rousseau's *Émile,* this is equally true of the allurements of the *beau monde,* politics, women's clubs and other feminist activities. "*Joie de rue, douleur du maison.*" So far as infant welfare is concerned, the *mater togata* becomes a home-breaker rather than a home-maker. The infant has a much better chance of surviving in rural or suburban districts than in the crowded cities, but as John Burns says, town life is not necessarily bad, "given good mothering, good food and plenty of it." Ashby* shows that infant mortality in the crowded Jewish quarters of towns is always low, in spite of overcrowding, defective housing and poverty, because the Jewish people set a great deal of store by home life and affection for children is strong among them. Infant mortality is very low in rural Ireland where maternal love is strong through the attractive human side of the women, and where poverty induces breast feeding. It is also low in some parts of rural England. During 1730–79, as Edmonds showed, the London mortality rate under 5 years was 66.2 per cent., during 1780–1829 only 37.7, while in 1911–15, it had fallen to 16.8 (Chalmers). About 1870, there began to be a uniform decline in infant mortality, for reasons given below, but there was no general fall until 1900, as shown by the following tables of five-year mortality in different countries (cited by Holt):†

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* Medin, O., Jahrb. f. Kinderheilk., Berlin, lxxiv (1911), p. 490.

† Holt, L. E., Proc. Am. Assoc. Study & Prev. Inf. Mortal. (1913), p. 33. For a full account of infant mortality and infant welfare activities in Europe, see Säuglingsfürsorge und Kinderschutz in den europäischen Staaten, hrsg. von Arthur Keller und Chr. J. Klumker, Berlin (1912). For American developments see Philip Van Ingen in A Half Century of Public Health (Ravenel) New York, 1921, 290–322.

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* See the "Historic Note" of A. K. Chalmers in National Health Insurance Medical Research Committee, "The Mortalities of Birth, Infancy and Childhood." London (1917), p. 10 *et seq.*

† Holt, *op. cit.*, p. 35.

	England	Ireland	Scotland	France	Germany	Italy	Belgium	Norway	Sweden
1881–5	129	94	117	167	207	175	156	99	116
1886–90	145	95	121	166	208	175	163	96	105
1891–5	151	102	126	171	205	185	164	98	103
1896–1900	156	106	129	159	201	168	158	96	101
1901–5	138	98	120	139	190	168	148	81	92

The infantile mortality rate per 1000 for England and Wales during 1900–1921 was 154 (1900), 151 (1901), 133 (1902), 132 (1903), 145 (1904), 128 (1905), 133 (1906), 118 (1907), 121 (1908), 109 (1909), 105 (1910), 130 (1911), 95 (1912), 108 (1913), 105 (1914), 110 (1915), 91 (1916), 96 (1917), 97 (1918), 89 (1919), 80 (1920), 83 (1921). A sudden ascent of the curve in 1904, 1906, and 1911 is attributable to unusually dry, hot summers, or other conditions inimical to infant welfare, but a laudable decline in the rate is noticeable. The causes of this decline since 1870 and particularly since 1900 are simple. After the introduction of Listerism (1869-70), surgical cleanliness became more and more popular, and to some extent affected milk and stall hygiene. In the same period, the causes of infant mortality, especially from diarrhea were carefully studied, and medical officers of health generally attempted to remove the conditions favoring it. From 1900 onward, the movement for infant welfare, a sort of twentieth century science, because well established. The infant welfare movement is mainly of French origin. Along with the decline of pediatrics as a specialty in England and France there has grown up an extension of social or preventive pediatrics, which is one of the brightest phases of modern medicine. This has been due to the fine humanitarian spirit of certain French and English writers and publicists and to the brilliant modern group of talented English public health officers, whose labors have more than set off the curious disinclination of the English physician to practise pediatrics in and for itself. On November 14, 1884, Firmin **Marbeau** (1798–1875), mayor of the first arrondissement of Paris, founded the first *créche* or day-nursery, where working mothers could leave their infants in willow cradles, usually in charge of a nun, with two attendants to rock the cradles. Nine other créches were founded in Paris during 1844–47. In 1847, a *Société des crèches* was formed, and the idea spread from France to Austria, Italy and Germany. There are now crèches all over Europe, usually supported by private benevolence. The principal service of crèches, according to Holt, has been to arouse the interest of the public in regard to infant welfare and the needs of working mothers. In 1862, Victor Hugo published his great epic of the misery of the poor (*Les Misérables*) and in 1869, another brief for child protection (*L'homme qui rit*). If it be true, as Schiller says, that "the brave man thinks of himself last of all," there can be no more poignant moment in literature than the feeling of the long-imprisoned Jean Valjean that the children confided to his care will have disappeared from life and that he will never see them again. In the beautiful episode of Cosette, the evils of baby-farming are laid bare, and Jean Valjean attains to his full spiritual stature through his friendship for a forlorn little child. These tokens of an enlarged interest in friendless children, preceded in England by Oliver Twist (1837–38), Nicholas Nickleby (1838–39), Old Curiosity Shop (1841), A Christmas Carol (1841), and David Copperfield (1850), were not without their sequel. Sir Robert Peel's Factory Health and Morals Act of 1802 for the preservation of the health and morals of apprentices and employees in cotton mills had little effect upon the terrible hardships endured by English factory children since the eighteenth century. In the vigorous humanitarian agitation against child labor which followed, it was shown that children bound to apprenticeship were, on occasion, actually sold into slavery with the effects of a bankrupt, or transferred from one hard-hearted, tight-fisted taskmaster to another; that "cruelties the most heart-rending were practised upon the unoffending and friendless creatures who were thus consigned to the charge of master manufacturers; that they were harassed to the brink of death by excess of labor, that they were flogged, fettered and tortured in the most exquisite refinement of cruelty; that they were in many cases, starved to the bone while flogged to their work; and that even, in some instances, they were driven to commit suicide."* It took all the spirited zeal of Robert Owen (1812–29), all the passionate eloquence of Richard Oastler (1829–33) and M. T. Sadler (1829–35), all the able pamphleteering of William Cobbett and John Fielden (1836), all the tact and dignity of Peel and Lord Ashley to finally reduce the number of working hours and alleviate the condition of these unfortunates, through the Factory Acts of 1819, 1833, 1844, 1864, 1867, 1874, 1878, and subsequently. Infant mortality was vigorously discussed at the Dublin meeting of the National Society for the Promotion of Social Science (1861), at the Philadelphia meeting of the Social Science Association (1871), at the International Congresses of Hygiene at Brussels (1876), Paris (1878), and later. In 1865, the *Société protectrice de l'enfance* was organized in France and in 1876, the Society for Nursing Mothers (*Société d'allaitement maternel*). In 1872, the English "Life Protection Act" was passed requiring registration, licensing and inspection of all places where infants were farmed out away from their parents. In 1874, came the famous *loi Roussel*, for the protection of infants sent into the provinces from Paris for wet-nursing. This law required government inspection of all places where infants under two years were farmed out, nursing rooms and *crèches* for all nursing mothers working in factories and inspection of the same. About 20,000 infants had been sent out in this way, with a subsequent mortality of 75 per cent. The author of this splendid piece of progressive legislation was a physician, Théophile Roussel, the most eminent of medical statesmen, and a forerunner of the time predicted by Jacques Loeb, when scientific men will have a voice in legislative assemblies.

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* T. Ashby, Hugh, "Infant Mortality." Cambridge (1915), pp. 25–26.

† Holt, *op. cit.*, p. 38, footnote.

Théophile **Roussel** (1816–1903), the son of a country doctor in the department of Lozère, graduated in medicine at the Paris Faculty with a dissertation on pellagra (1845), a subject which he subsequently handled in two large treatises (1845, 1866), made valuable researches on the hygiene of workers in match factories (1847), the mercury miners at Almaden (1847–49) and other occupations, and wrote a life of Pope Urban V (1841), a manual of match fabrication (1847), a *Concours* on the value of physical signs in heart disease (1847) and studies on correctional and preventive education (1879). In 1845, he went into politics and was elected to represent his native department of Lozère (1849). Being a republican, he gave up his seat after the *coup*

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* Fielden, John, "The Curse of the Factory System." London (1836), p. 10, cited by R. W. C. Taylor in "The Modern Factory System." London (1891), p. 189.

d'état (1851) and did not seek election until after the events of 1870–71, when he became deputy from the arrondissement of Florac (1876) and senator in 1879. In 1872, he took the initiative in a law for suppressing public drunkenness, which was followed by the three crowning achievements of his life, the laws of December 23, 1874, for the protection of infants sent out to nurse (*loi Roussel*),* of July 25, 1889, for the protection of morally abandoned or maltreated children, and of July 17, 1893, for the organization of medical charity. He was honorary president of the *Société protectrice de l'enfance* in 1893. On December 20, 1896, a touching jubilee was held in his honor at the Sorbonne. Disclaiming any credit for himself, Roussel said, with charming simplicity: "*C'est la fête de Protection de l'Enfance.*" Modest to a fault, he demanded that no eulogies be pronounced at his funeral, but an inspector general returning from his native Lozère said: "That is a land where there are no orphans, for those who have lost their parents have *le père Roussel* to take care of them." The ruling principle of Roussel's life was to translate charitable sentiment into enacted law. Through his persuasive eloquence and his personal charm, he came to be known as "the advocate of abandoned children."†

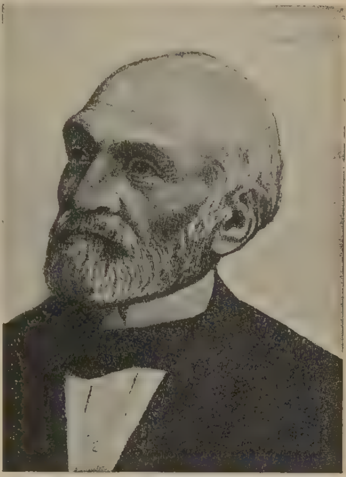
FIG. 52.—Théophile Roussel (1816–1903).

Following the *loi Roussel* came a long series of laws for the protection of maternity, forbidding the employment of women in factories for a statutory period before and after confinement. The initiative was taken by Switzerland in a law of 1877, requiring a rest of two weeks before and six weeks after the birth of the child, the pre-natal period being lengthened by a law of 1897. This example was followed by Hungary (1884), Austria (1885), Holland (1889), Belgium (1889), England (1891), Germany (1891), Portugal (1891), Norway (1892), Spain (1900), Sweden (1901) and Denmark (1901) (Holt). The first consultation for nurslings (*consultation des nourrissons*), an adjunct to maternity hospitals at which infants are regularly weighed and examined and mothers instructed in infant nutrition and hygiene, was organized by Pierre Budin at Paris in 1892. In 1893, Variot began to distribute milk at the Dispensaire de Belleville (Paris). The first milk depot (*goutte de lait*) was established at Fécamp by Dufour in July, 1894, with the object not merely of distributing clean milk to indigent mothers, but of encouraging breast-nursing in every way. Holt lists the following national and international conferences on infant welfare:

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* For the text of the *loi Roussel* and subsequent infant welfare legislation in France, see Säuglingsfürsorge und Kinderschutz in den europäischen Staaten (Keller and Klumpke), Berlin (1912), pp. 1266–1325.

† For an extended account of the career of Roussel, see F. Houssay, Gaz. méd de Paris, iv (1904), 12 s., pp. 169, 181, 217, 229.

> "The National Congress for Infancy at Florence in 1896; the League against Infant Mortality, Paris, in 1902; the International Congress of Milk Depots, in Paris, in 1905; the National Conference on Infant Mortality, in London, in 1906; the International Union for the Protection of Child Life, in Brussels, in 1907; a large exhibit in Berlin in 1908, portraying the problem of infant mortality in all its phases; a second National Conference on Infant Mortality, in London, in 1908; the German Society for the Protection of Infants, in Munich, in 1909; the American Association for Study and Prevention of Infant Mortality, organized at New Haven in 1909; the Third International Congress for the Protection of Infant Life, in Berlin, in 1911; the English-speaking Conference on Infant Mortality, in London, in 1913."*

For the widespread awakening of interest in infant mortality, as indicated by these foregatherings, Holt assigns three causes, *viz.*, the growth and extension of the humanitarian spirit, the concern of modern states about depopulation, and the great advances made in preventive medicine during the last thirty years. It is not without reason that France has been the pioneer and principal advocate of infant welfare activities, for the steady falling in the French birth rate could only spell national and racial extinction in the end. And from France came the most impressive lesson in the science of attacking the problem of infant mortality at its source. During the ten years 1893–1903, the infant mortality of Villiers-le-Duc, a small village in the Côte d'Or of France, was known to be a stable zero. This came about in the following way. During the period 1804–54, the rate of infant mortality in Villiers-le-Duc fluctuated between 30 and 20 per 100. During the period 1854–63, however, it fell to a steady 15 per 100. This was due to the fact that the mayor of the little commune, M. Morel de Villiers, was interested in hygienic problems, and applied certain rational principles to the welfare of the babies in his district. After his death (1886), his two successors took no interest in these matters and the infant mortality rate immediately went up to 30 again. In 1884, his son, M. **Morel de Villiers,** an ex-army officer, became mayor, and applied his father's methods to such good purpose that the mortality rate immediately fell to 15.4 per 100 during 1884–93, and to zero during 1893–1903. In the meantime, M. Morel had studied and graduated in medicine.

The methods of the father were, in brief, the insurance of every woman with child, married or unmarried, at the expense of the mayoralty by the declaration of pregnancy before the seventh month; the assurance of free medical aid out of a village fund in all cases adjudged dangerous by the midwife; a grant of $0.20 *per diem* out of the same fund to every woman remaining in bed six days after her confinement; compulsory sterilization of milk, with appropriate apparatus, by all mothers or wet-nurses unable to nurse their infants at the breast; the systematic weighing of newborn infants every fortnight on a communal weighing machine, as a check upon the infant's condition; the compulsory notification of any illness in the infant within 24 hours after its appearance; the withdrawal of qualification certifications from all wet-nurses not complying with these regulations, and the award of a bonus of $0.50 to any nursing woman who could produce a one-year-old child in good health as a result of her nursing during the period paid for.

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* Holt, *op. cit.*, p. 43

These admirable provisions,* which contain all the essentials of recent infant welfare activities and which were printed as a definite municipal ordinance by M. Morel de Villiers on May 11, 1903, attracted the attention of Benjamin **Broadbent,** who became mayor of the county borough of Huddersfield, England, in order that he might get some definite action on the infant mortality problem. Later, Dr. Samson G. H. **Moore,** medical officer of health of the same community, took up the question. During 1892–1902, the rate of infant mortality in Huddersfield was 148 per 1,000 and in 1902 it was 138 per 1,000. In 1901, it was 132, as against 182 in Northumberland, 179 in Durham and Lancashire, 91 in Wiltshire and 95 in Rutlandshire and Westmoreland. During 1902–4 Dr. Moore made a careful analysis of infant mortality in Huddersfield, in the light of Morel's findings, and his admirable report of 1904, showing that nearly half of the babies had died from preventable causes, is now exhausted in its fourth edition.† In November, 1905, Mr. Benjamin Broadbent was elected mayor of Huddersfield, and on November 10, in his mayoral address, he announced that, at the birth of every child born in Huddersfield during his term of office, he would issue a promissory note of £1, payable to that child on its first birthday, if it lived through that period. This announcement attracted wide attention to the cause of infant welfare in the medical and newspaper press. In the meantime, as a result of Dr. Moore's report, final approval had been obtained from the sanitary authority (April, 1905) of a plan for "voluntary notification of birth to the medical officer of Huddersfield and the visitation in their homes of all newly born infants, immediately after birth, by women doctors, followed by voluntary workers," in order to instruct the mother as to the proper mode of nursing and caring for her offspring. Prior to 1906, the English law of 1837 required registration of births at any time within 42 days after birth. This arrangement delayed registration over six weeks. In 1906, the Borough of Huddersfield obtained parliamentary powers requiring notification of all births of the medical officer of health within 48 hours after birth. In the following year, Parliament passed an adoptive Notification of Births Act (1907), requiring notification of birth in addition to registration, by the father or other responsible person, to the medical officer of health within 36 hours after birth, under penalty of a fine of 20s. In 1915, this Act was supplemented by the Notification of Births (Extension) Act, extending the 1907 Act to areas in which it had not been adopted, and vesting any local authority with the powers of a sanitary authority, under the Public Health Acts of 1875–1907 or the Public Health (London) Act, 1901, for the purpose of promoting the care of expectant mothers, nursing mothers and young children. In other words, the properly authorized local authority is empowered to follow up all maternity cases to promote the welfare of mother and child and the Local Government Board has latterly agreed to defray half the cost of carrying out any plan for maternal and child welfare approved by the Board. In 1907, the infant welfare movement in Huddersfield came into full operation. The infant mortality rate fell from 134 per 1,000 in 1906 to 97 in 1907, the locus of infant mortality remaining at about that level subsequently. There were similar activities in other parts of England, contemporaneous with those at Huddersfield. In 1906 Dr. Archibald K. **Chalmers,** medical officer of health of Glasgow, made a study of infant mortality in the Scotch towns.* He found every movement of the infant mortality curve "an exaggeration," always higher in Scotland than in England, although the general death rate of England is higher than that of Scotland, and "invariably lowest in Ireland." The low rate of the insular rural districts corresponded with that of the residential suburbs of the large cities, and the chief increase was noticeable in the small towns and rural inland districts, rather than the large manufacturing centers. In Glasgow, the total rate was lowered by 15 per cent., representing a decrease of 30 per cent. in the proportion of deaths during the sixth to the twelfth months, and 16 per cent. in the third to the sixth months, while the rate during the first three months remained practically stable. The deaths in these three months were found not to be due to disease in the ordinary sense, but to defective vitality, syphilis, alcoholism, parental cell deterioration and other ante-natal causes. The hereditary diseases threatening the newborn infant are of the kind which, in Chalmers' phrase, "*strike vertically*," while the ordinary intercurrent diseases of the after-period have a lateral or casual incidence. This important point was sensed by Karl Pearson when he found it impossible to fit the actual curve of infant mortality into his theoretical curve without taking into account the whole range of pre-natal influences.† Thus, given the

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* For the text of which, see Moore, S. G. H., Lancet, London, i (1916), p. 944. Also Broadbent, To the Mothers of Huddersfield: An Open Letter, Huddersfield (n.d.), pp. 7–10.

† Moore, S. G. H., County Borough of Huddersfield. Report on Infant Mortality. 4 ed., Huddersfield (1907, *vel subseq.*).

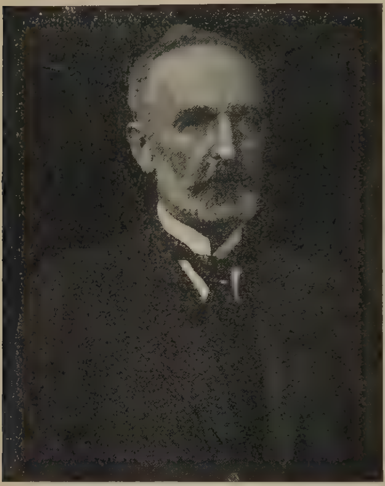

FIG. 53.—Sir Arthur Newsholme.

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* Chalmers, A. K., Pub. Health, London, xviii (1905–6), pp. 409–438.

† "Pearson, Karl, The Chances of Death." London, i (1897), pp. 24–39. For a statistical examination of the ante-natal causes of infant mortality, see Fulton (J. S.), Tr. Am. Assoc. Study and Prev. Inf. Mortality, Baltimore, i (1910), pp. 115–152.

stationary character of the death rate during the first three months of life, vitality is "a quality of the child at birth rather than the accident of its surroundings afterwards" (Chalmers). In the important reports rendered to the Local Government Board by its medical officer, Sir Arthur **Newsholme** (1910),* it is shown that "excessive mortality in infancy implies excessive mortality in later life, that there is no essential causal relation between a high birth rate and a high rate of infant mortality," but that "a high infant mortality implies a high prevalence of the conditions which determine national inferiority"; that poverty connotes a high infant death rate, although breast-feeding is commoner among the poor than the rich; that early motherhood exerts a slight effect upon high infantile mortality; that infant mortality in the first month of life is preventable, as also the high rate in crowded centers of population. In his subsequent reports (1913–16), Newsholme shows that more than half of infant mortality is due to infection from without, that the large maternal and infant mortality from puerperal hemorrhage, convulsions, and septicemia are due to bad midwifery; that the causes of infant mortality are many, *e.g.*, maternal ignorance, lack of medical attendance and nursing, the fecklessness of mothers, poverty, intemperance, overcrowding in areas or in rooms, defective sanitation, industrial employment of married women, large families, infectious and diarrheal diseases; and that the devices of infant welfare activity should be varied, *viz.*, proper housing, intra- and extra-domiciliary sanitation, sufficient and proper food, notification of births, medical attention and nursing and pre-maternity work, including care, feeding and instruction of the mother. The dictum of Sir George Newman† that infant mortality is less connected with external conditions than with ignorance of the mother is obviously one-sided. Infant mortality is of multiplex causation and must therefore be met by multiplex infant welfare activities. "Infant mortality," says Newsholme, "is the most sensitive index we possess of social welfare and of sanitary administration, especially under urban sanitary conditions." This sentence is the keynote of the infant welfare movement, for, as Holt says, many whom the fanatical evolutionists would regard as the physically unfit are really "victims of a bad environment, improper feeding and neglect." A high infant mortality means "the sacrifice of the *unfortunate* rather than the *unfit*," who must be eliminated "by birth, not by death."

The present infant welfare movement implies the widest extension of the activities of social medicine, from puericulture or ante-natal supervision, including pregnancy clinics, insurance of maternity, maternity homes, schools for mothers; and post-natal supervision, from day nurseries (*crèches*), milk stations, nursery schools, consultations for nurslings to school-inspections, child-study, mental tests, school-lunches (*cantines*), child-labor legislation, child-welfare activities, play centers, vocational aptitude studies, instruction inhome economics, and training for parentage.

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* Great Britain. Local Government Board. Supplement to the 39th annual report, containing a report by the Medical Officer on infant and child mortality. London (1910), pp. 34–36; 74–78, by Sir Arthur Newsholme. Later reports: (1907–11), London (1913); Infant Mortality in Lancashire (1913); Maternal Mortality (1915); Child Mortality at Ages 0–5 (1916). See, also Report of Local Government Board on "Maternity and Child Welfare," London (1917). For a full account of infant welfare in the United Kingdom, see the histories by A. Dingwall Fordyce and T. J. Stafford in Säuglingsfürsorge und Kinderschutz (Keller and Klumker), Berlin (1912), pp. 349–440.

† Newman, Sir George, "Infant Mortality" (1906).

Recent English legislation bearing on maternal and infant welfare comprises, besides the Notification of Births Acts of 1907 and 1915, the Housing of the Working Classes Acts (1885–1903), the Compulsory Infectious Diseases (Notification) Extension Act (1899), the Factory and Workshop Act (1901), the Midwives Act (1902), the Children Act (1908), for protecting wet-nursed infants beyond the Infant Life Protection Act of 1897, the Housing and Town-Planning Act (1909), the National Insurance Acts (1911, 1913), the Milk and Dairies Act (Consolidation) Act (1915), the Public Health (Venereal Diseases) Regulations (1916), the Midwives Act (1918), and other war measures. Florence Nightingale's letters of 1891–2 on health visiting in rural districts were reprinted in 1911.* Milk depots were established at St. Helens (1899), Finsbury (1914, and elsewhere. The first schools for mothercraft were started at St. Marylebone (February, 1906) as the Borough of St. Marylebone Health Society, which opened an Infant Consultation on May 10, 1906. Winchester followed in December, 1906.† The St. Pancras School for Mothers was founded in 1907 and followed by other schools at North Islington (1914), Stockport (1914) and elsewhere. In June, 1918, a long list of English welfare associations and schools for mothers was given in the massive report of the Carnegie United Kingdom Trust on the physical welfare of mothers and children by E. W. Hope of Liverpool and Miss Janet M. Campbell (Liverpool, 1917). Dr. Barnardo's homes for nurslings at Hawkshurst, the Children's Home at Sidcup, Kent, the London School for Myopes, the Downs Ringworm School at Sutton (Surrey) for children afflicted with tinea, are other phases of English activities.

The first National Conference on Infantile Mortality was held in the Caxton Hall, Westminster, on June 13–14, 1906; the second on March 23–25, 1908; the third on August 4–5, 1913, all under the presidency of John Burns. To these conferences such able medical officers of health as James Niven (Manchester), J. Spottiswoode Cameron (Leeds), G. F. M'Cleary (Hampstead), James Robert Kaye (West Riding), John F. J. Sykes (St. Pancras), E. W. Hope (Liverpool), S. G. H. Moore (Huddersfield), A. W. Chalmers (Glasgow), George Reid (Staffordshire), as also Mayor Broadbent, Sims Woodhead, J. W. Ballantyne contributed valuable papers on infant mortality. At the third conference Van Ingen, Shaw, Talbot, LaFetra and other American pediatrists took part. International congresses for the study and prevention of infant mortality, originally inspired by the French Consultations des Nourissons and the Gouttes de Lait, have been held at Paris (October 21, 1905), Brussels (September 12–16, 1907) and Berlin (September 11–15, 1911). In Canada, admirable reports on infant mortality have been made to the Registrar General of Ontario by Dr. Helen MacMurchy (1910–12).

In 1910, Dr. Janet E. Lane-Claypon, on behalf of the Lister Institute, made a journey through Germany, Sweden and Denmark, to study modes of prevention of infant mortality.‡

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* Letters from Miss Florence Nightingale on Health Visiting in Rural Districts. London, P. S. King and Son (1911).

† Pritchard, E., Lancet, London, i (1917), p. 352.

‡ In a MS. kindly lent by Miss Ellen C. Babbitt. For the history of infant welfare in Germany, see, also, Arthur Keller's article in Säuglingsfürsorge und Kinderschutz (Keller and Klumker), Berlin (1912), pp. 185–311.

German activities at that time included milk kitchens, with baby consultations in most of the large towns; maternity insurance; nursing bonuses of 1.–4.8 marks to mothers who nurse their own children; a free hospital, established in Dresden by Schlossmann, for all sick, illegitimate or parentless children whose relatives could not pay for them; homes for illegitimate or other Poor Law children, to get them in good health prior to boarding out; regulations for police supervision of all children under four who are boarded out in German towns (1879), and revised regulations for the police inspection of these children in Berlin (1890); a system of *public guardianship* of illegitimates, established at Leipzig by Dr. Max Taube (1904), whereby all illegitimate children born in Leipzig become at once the wards of the municipality under his personal care; systems of *collective guardianship* of illegitimates in Strassburg, Danzig, Breslau, Mannheim, Freiburg, Berlin, Dresden, Hamburg, Halle, Kiel and other towns; a Kinder-Asyl for the reception of all Poor Law children in Berlin (1901), Breslau (1903), Hamburg (1907) and elsewhere; supervision of children in foster homes; a number of private institutions for nursing mothers; the attempt to supply wet-nurses in Dresden and Berlin; syphilitic nurses for syphilitic children; a few private institutions for nursing mothers; forest and seaside homes, sanatoria and holiday camps for sick and convalescent infants; and a Society for the Prevention of Infant Mortality which held its first meeting at Dresden (1909). There is a sick-insurance law protecting women six months before and six months after childbed; and a provision for suckling-money (*Stillgeld*) for working mothers. On June 4, 1909, the Kaiserin Auguste Victoria Haus, the headquarters of all German efforts against infant mortality, was opened in Berlin. This institution, planned under the patronage of the Empress, and designed to be (at Heubner's instance) "an institute for the physiological investigation of infant nutrition, with clinical treatment," was constructed at a cost of the $625,000, collected by public subscription. It was intended to be a model institution for scientific research on infants of all ages and in all states of health, where all phases of infant life, post-natal and ante-natal, may be found, with provision for the care of confinement cases and sick babies from all classes of society and the training of educated women as nurses. It is said that the results of this extravagant outlay did not come up to expectations. Germany is only surpassed by Russia, Austro-Hungary and Roumania in infant mortality. A guardianship office and welfare station, for prompt financial aid and care of expectant mothers and their infants, exists at Charlottenburg. There are also two leagues providing workers to take care of a home during the lying-in period. On the didactic side, effective object lessons were furnished at the Dresden Hygienic Exhibit in 1911. The different milk-kitchens, day nurseries, infant hospitals, etc., of Germany were shown on a map with colored pegs. The average gastro-enteritis mortality during 1880–1909 was shown to be inversely as the scale of living, *viz.*, zero in the wealthy, 4.8 per 1,000 in the upper middle classes, 36.1 in the lower middle classes, and 59 among the poor. The Wassermann test showed 10 per cent. of latent syphilis in wet-nurses. The exhibits included correct clothing for a baby, sanitary and unsanitary toys, unhygienic nursing bottles, models of ophthalmia neonatorum, degrees of dental development, the infant stomach and its contents, casts of infant stools, models and photographs of rachitic infants and a box of coins, showing that out of a working man's income of 1,380 marks ($395), 360 went for housing, 560 for food, 140 for clothing, 360 for amusements and 160 for alcohol.* It has been objected against the modern German care of infancy in hospitals that, in spite of the splendid organization of applied science, the movement was more or less an expression of the concern of the metallic Prussian bureaucracy about the decline in the birth rate, and that there was a certain lack of humanistic "mothering" which is deemed so essential in Anglo-Saxon countries. "You have seen all the splendid provisions for studying the proper care of babies, but have you seen the babies themselves?" was the question put by Professor Medin of Stockholm to women who were visiting the Berlin establishments. The importance attached to cradle-songs, dandling, fondling and other modes of diverting the infant in Hellenistic pediatry is emphasized in Sister Mary Rosaria's dissertation "The Nurse in Greek Life" (Boston, 1917). This is naturally a field in which women excel.

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* For the above facts, I am indebted to Miss Ellen C. Babbitt.

In Hungary, under the laws of 1901–3, every child under 15, if not otherwise provided for, is entitled to state care, food, education and a home (Van Ingen). This is managed by state asylums, each under a medical director, and 374 State Children's Colonies, or foster homes. Delicate, sickly children are kept in the asylums until they can be entrusted to the foster parents, and are afterward constantly watched by a local physician and visiting nurses. Mothers of babies in the asylums are given financial support if they nurse them, and may accompany them to the foster homes. A model lodging house fits the unassisted man to get a job by fumigating, cleaning and mending his clothes (Babbitt). Between $1,500,000 and $2,000,000 were expended for the state care of children in 1910. The total mortality of nurslings in asylums was 11.2 per 100, and 10.89 in foster homes.

In Spain, a Superior Council for Child Welfare, presided over by the Minister of the Interior, looks after all children under 10 years of age, supervises crèches, asylums, hospitals and the training of midwives and protects children in care of foster parents. As part of the administration under the Superior Council, there are 49 provincial bodies and over 6,000 local bodies which attend to details of this mode of social service.

In Holland, infant welfare is in charge of Dr. Saltet, head of the Health Department of Amsterdam and professor of hygiene in the University. The statistics show a low mortality rate, particularly among the Jewish families of Amsterdam, among whom breast nursing is the rule. Between 1895 and 1910, there was a decrease of 55.7 per cent. in the infant mortality rate. The obstetrician Treub maintains that abortion is increasing.

In Sweden, the Allmänna Barnhuset or Public Orphanage, founded about 1760, insures breast feeding for four months after birth, by allowing the mother to remain in the institution with her child. At the same time she nurses another child. This regulation once complied with, her child is adopted as a ward of the foundation for 14 years. If the mother does not comply, a sum of 600 kronor ($162) must be paid for the maintenance of the child, the mother renouncing all rights to it henceforth. Poor Law children also become wards of the Orphanage, the city of Stockholm paying 400 kronor for the maintenance of each. This applies to poor children from all parts of Sweden. Children weaned at four months are boarded out with foster parents. About 5,200 children are taken care of annually and about 850 babies in the Orphanage. The average mortality in the Orphanage was 12.16 per cent. in 1894–8 and 10.7 per cent. in 1899–1903 (Lane-Claypon).

In New Zealand, the Royal Society for the Health of Women and Children, centralized in Dunedin, with eight local branches in other parts of the dominion, and seventy subsidiary committees, has done capital work. It is sometimes called the Plunket Society, after the Governor General and his wife, Lord and Lady Plunket, who are its patrons. Its field agents are the so-called Plunket nurses, who, each of them, look after one of the districts into which the two islands are subdivided, giving instruction in all branches of the art of motherhood, even in girls' schools. There is a complete system of birth registration and close government supervision of midwives, maternity hospitals, infant asylums and nurses. The aim is essentially modern, to teach girls and women the duties and responsibilities of maternity and infant welfare. The result of these activities has been to reduce the infant mortality from 83 to 51 per 1,000 in ten years, while at Dunedin it is now 40 per 1,000 (4 per cent.), as against 150 in Berlin, 120 in Paris and New York, 100 in London. This is the best record yet obtained in a community of size. The highest infant mortality rate is that of Chile (333 per 1000).

In the United States the infant welfare movement is of comparatively recent growth, partly owing to the fact that there has been no uniform system of birth registration. New Zealand, Hungary

Germany, and Sweden have gone far to solve the problem of poverty for the people. New Zealand has solved the problem of teaching the people how to live. These are paternalistic activities carried forward in populations practically homogeneous in respect of racial and national sentiment. Our problem is one of heterogeneity of race, racial psychology, and "sectional" feeling. It is highly significant, in this regard, that many of the principal pioneers and prime movers of social service in America have been women.* Special credit is due to Philip **Van Ingen** (1875–), of New York, for his painstaking and valuable work in assembling annual comparative tables of infant mortality from the vital statistics of the health departments of states and large cities, prior to the actual publication of these reports.

Rochester, New York, was the first American city to have a Milk (Welfare) Station (1897), and now maintains ten during the summer months. Boston, Chicago, Cleveland, Philadelphia, Richmond employ visiting nurses for pre-natal work and instruction to expectant and actual mothers. In 1902, a Milk Fund Association was started in Cleveland, to supply modified milk and medical attention to infants brought to a central station. In 1904, a farm was acquired, and certified milk was thereafter distributed instead of milk modified according to a percentage formula. In 1906, the Milk Fund Association combined with the Visiting Nurse Association to form an infant clinic, and maternal instruction was then given by visiting nurses attached to the clinic. In December, 1906, this work was taken over by the Babies' Dispensary and Hospital, and in 1907, the Milk Fund Association amalgamated with and turned over all its property to the Babies' Dispensary and Hospital. Branch dispensaries (Babies' Prophylactic Dispensaries) were then formed to look after the hygiene of normal infants, while the central dispensary attended to the sick. There were six of these branch establishments in 1908, all under one medical director and one supervising nurse. In 1910, a dispensary building was erected, with a milk laboratory, lecture room, consultation rooms and other accessories. In 1911, Cleveland appropriated $10,000 for infant welfare work and established five public prophylactic dispensaries and a department of child hygiene in charge of the medical director of the Babies' Dispensary and Hospital and its supervising nurse. By combining the original branch dispensaries, the city had thirteen branch dispensaries at the end of 1911. Special nurses now look after infantile blindness, foster homes for babies, and the teaching of infant hygiene in girls' schools. Finally, the medical director of the establishment is now professor of pediatrics in Western Reserve University, and eight hours in the compulsory curriculum are devoted to practical training in infant welfare work.

Up to 1902, the Department of Health of New York City employed special physicians to look after sick babies in the tenements. In 1903, visiting nurses were also detailed to follow up these cases, and general milk inspection was begun. On August 19, the Division of Child Hygiene was established with Dr. S. Josephine **Baker** as chief, and a staff of 161 medical inspectors and 142 nurses. The functions of this division are the control and supervision of midwives, the instruction of mothers in infant hygiene, the inspection and sanitary supervision of day nurseries, the supervision of foundlings in foster homes and institutions for dependent children, the medical inspection and examination of school children and the enforcement of the child labor law in relation to employment certificates. In the summer of 1911, 79 milk stations were operated, 15 by the Health Department, 31 by the New York Milk Committee, and 33 by other organizations. An Infant Welfare Association, afterward known as the Babies' Welfare Association, was formed by the amalgamation of 150 different infant welfare associations. During 1904–10, the average infant mortality in New York was 16,527. In 1911, it fell to 15,030, in 1912, 14,289, in 1913, 13,797. The infant mortality rate fell from 280 per 1,000 in 1880 and 144 in 1908 to 102 in 1913. Outside of New York City the infant mortality rate in the state fell from 125 in 1913 to 111 in 1914. The present motto of the New York Health Department is: "Public health is purchasable; and within certain limits each community may determine its own death rate."

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* Among these may be mentioned Miss Julia C. Lathrop (Washington), Dr. S. Josephine Baker (New York), Dr. Helen MacMurchy (Toronto), Miss Ellen C. Babbitt (Washington), Dr. Grace L. Meigs (Washington), Dr. Alice Hamilton (New York), Dr. Mary Sherwood, Dr. Lillian Welsh and Miss Gertrude B. Knipp (Baltimore), Mrs. William Lowell Putnam (Boston), Miss Jane Addams (Chicago).

Work along the same lines has been done by the Committee on Infant Social Service of the Women's Municipal League of Boston (1909), the Pregnancy Clinic of the Boston Lying-In Hospital (1912), the Visiting Nurse Association of Bridgeport, Connecticut (1912), the Social Service Department of the Washington University Hospital, St. Louis (1912), the Division of Child Hygiene of the Kansas State Department of Health (1915), and similar organizations in Massachusetts, Ohio, Louisiana, Texas and other states. Public lectures, exhibitions, exhibit cars, "Little Mothers' Leagues," and "Baby Weeks" and "Better Babies" contests are varied features of infant welfare work. Nation-wide Baby Weeks were held in 1916 and 1917 under the auspices of the Children's Bureau and the General Federation of Women's Clubs, and 1918 was made a "Children's Year" for the inauguration of a rational program of child welfare in wartime. A Back-to-School drive was instituted October 17, 1918. In 1915, there were 462 infant welfare stations in different American cities. Of these, 290 are maintained by private organizations in 92 cities. In 1909, the American Association for the Study and Prevention of Infant Mortality was organized. In 1912, the United States Government established the Federal **Children's Bureau** at Washington, under the direction of Miss Julia C. **Lathrop,** a former associate of Miss Jane Addams at Hull House, Chicago. The object of this Bureau is the investigation of "all matters pertaining to the welfare of children and infant life." The Children's Bureau has made important surveys of the status of infancy and infant mortality in Johnstown, Pennsylvania, Montclair, New Jersey, and Manchester, New Hampshire. A complete life history of every baby born in a particular year in these localities has been obtained, and if the baby died within the year, the causes of death were investigated. In Johnstown, a city made up largely of East European immigrants, it was shown that there is a direct relation between bad sanitation, multiplex household drudgery and the varying mortality in the different wards. As shown at the Dresden Hygienic Exhibit, the infantile death rate is inversely as the annual income of the father. The average infantile death rate in Johnstown is 134 per 1,000, but 264 among the Serbo-Croats alone. In Montclair, a wealthy residential community, it is 84. In Manchester, an industrial town, it is 193, the principal cause being the daily occupation of the mothers in the textile mills. Among the English, Irish and Scotch, the rate is 66 per 1,000; among the French Canadians, it is 248. Artificial feeding and unduly large families explain the difference.*

By the passage of the Congressional act, effective September 1, 1917, the powers of the Children's Bureau have been enlarged by the establishment of a Child Labor Division to carry out the intent of the law. Recent American Child Welfare activities culminated in the Sheppard-Towner Bill (December, 1921) by which governmental aid is extended to states for the organizing of Divisions of Child Hygiene in the State departments of health or to assist those already formed.

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* For the information conveyed in this section, I am much indebted to the articles of Ellen C. Babbitt, Tr. Am. Assoc. Study and Prev. Inf. Mortal., 1911, Baltimore, ii (1912), pp. 64–71; L. Emmet Holt, *Ibid.*, iv (1913), pp. 1–54; E. B. Phelps, Tr. Internat. Cong. Hyg. and Demog. (1912), Washington, vi (1913), pp. 132–183; Philip Van Ingen, Am. Jour. Dis. Child., Chicago, vii (1914), p. 471; x (1915), p. 212; Grace L. Meigs, *Ibid.*, xiv (1917), pp. 180–197; and to the rich supply of literature and public documents on infant welfare kindly supplied me by Miss Babbitt and Miss Gertrude B. Knipp (Baltimore). For the activities of the Children's Bureau, Washington, see Miss Lathrop's reports (I–VII, 1913–19), and the many publications of the Bureau.

As a rule, the larger the family, the higher the infant death rate. Unwelcome children are not usually well cared for. Heartless parents will even allow children to die on their hands by starvation or exposure (*Engelmacherei*). This brings up the question of birth-control. As stated by Dr. Jacobi in 1915, the object of birth-control is to limit reckless and irresponsible begetting of children by deliberately regulating their number and the time of their arrival. It is maintained by the opponents of birth-control that, on the continent of Europe, where control is a commonplace right of women, the liberty has been a main coefficient in bringing about the depopulation of modern states and that, in the United States, it has the disadvantage of being connected with the sordid interests of "sexually exploited women" and of commercial drug firms. The present European war goes to show that a country with a small population may be in danger of being overwhelmed by a country with a teeming population, bred for military purposes. But, other things being equal, it cannot be denied that the general ideal of advanced modern states (at least in crowded cities) would be the moderate sized family; in other words, fewer but better children. Bernard Shaw closes with the subject in the following aphorisms:

> "The essential function of marriage is the continuance of the race, as stated in the Book of Common Prayer. The accidental function of marriage is the gratification of the amoristic sentiment of mankind. The artificial sterilization of marriage makes it possible for marriage to fulfill its accidental function while neglecting its essential one. The most revolutionary invention of the XIX Century was the artificial sterilization of marriage."

These sentences reveal to what extent the religious and moral inhibitions of the past have broken down under the influence of modern philosophy. In another place, Shaw observes that:

> "If we desire to maintain the population at its present figure or to increase it, we must take immediate steps to induce people of moderate means to marry earlier or to have more children. . . . The population declines because the high birth rate of the very poor is counterbalanced by a huge infantile mortality in the slums, whilst the very rich are also the very few and are becoming sterilized by the spreading revolt of the women against excessive childbearing—sometimes against any childbearing."

In spite of the advantages of early marriages—*viz.*, that they are apt to be more durable and that the early married are able to establish their children in life before they die—the depopulation of modern states continues because the conditions of modern life are such that most people are financially unable to marry early and because few modern women are physically adapted or mentally inclined to the demands of multiparity. Thus the birth rate of a nation in any period, as Havelock Ellis maintains, is regulated automatically by social and economic conditions. Lecky, in the "Map of Life," contends that the two influences which "inevitably and powerfully tend to depress the vitality of a nation" are "sanitary science itself, which enables great numbers of constitutionally weak children, who in other days would have died in infancy, to grow up and marry and propagate their offspring" and "the steady movement of populations to towns." He concludes that "the great diminution in infant mortality is in truth a very doubtful blessing." But these Tory squire arguments are pulverized by the very fact that the infant welfare movement originated, in the first instance, from a general alarm about the depopulation of modern states; while statistics have proven to the hilt the theorem of Newsholme that a high infant mortality rate in a crowded modern community connotes a high general mortality and a specific lowering of vitality in that community. It was formerly supposed that the weakest went to the wall, and women, even in our own time, would say of a dead infant: "It is better off in heaven." But the causes of a high infant mortality are of a kind that really affect all infants and all adults. In the past, when there were not so many people in the world, the law of the survival of the strong and brutal obtained with full force and "coward Adam" first made definite war upon the defenseless infant. Today, he has grown a little ashamed of himself. The main issue at stake in the present European war was to determine whether overbearing power can continue to play the cowardly bully toward the weak or wreak vindictive spite upon the defenseless.

In wartime, infant welfare activities acquire an additional prospective value through the fact that as the population continues to be killed off in the warring countries, the infants who are to replace them become more and more of a national asset. In all these countries, the birth rate has been steadily decreasing of late years.

In England, the starting point of preventive, as distinguished from palliative, infant welfare work, was a memorandum of the Local Government Board, of date July 30, 1914, outlining measures for ante-natal, natal and post-natal care, including systematic maternal and child welfare activities and insurance of maternity by means of a liberal grant of money from Parliament. Hospital treatment for infants, food for expectant and nursing mothers and infants under five, crèches, day nurseries, homes for deserted and illegitimate children, etc., were further provided for in the Circular of the Local Government Board of August 9, 1918. In spite of the fact that millions of women were eventually engaged in munition and other war-industries, the infant death rate steadily declined. The passage of the Notification of Births (Extension) Act in 1915 insured compulsory notification of births in all parts of the British Isles within 36 hours after birth. In March, 1914, there were 600 health visitors for the metropolitan boroughs, and in February, 1917, there were 1,445, and 800 district nurses. In June, 1918, there were 700 centers for maternity and infant welfare work, established by local authorities, 578 by voluntary societies, 751 whole-time health visitors, 760 part-time health visitors, 1,044 district nurses engaged by local authorities and 320 additional health visitors in the employment of voluntary societies.* The infant death rate of England and Wales in 1891–1900 was 153, in 1901–10, 128, in 1911–15, 110, and in 1916, 91, the lowest then attained. The birth rate was 23 in 1914–15, 22 in 1915–16, and 20.9 in 1916–17. In Scotland, the infant death rate fell from 126 in 1915 to 97 in 1916, also the lowest on record. On July 2–7, 1917, a National Baby Week exhibition was held in Central Hall, Westminster, as part of a general campaign of education. Maternity is practically insured and child welfare up to school age is forwarded. The Board of Education offers grants for mothers' schools and day nurseries, with standardized methods of procedure. Under the National Insurance Act, £650,000 were appropriated in 1914–15 to cover the deficit caused by the high sick rate among married women.*

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* Newsholme, Sir A., U. S. Dept. Labor Child. Bureau, Standards of Child Welfare, Rep. Child. Bureau Conf., Washington (1919), p. 279.

In Paris, the *Office central d'assistance maternelle et infantile* was organized in August, 1914, to insure public care of every pregnant woman and every child under three, "to be sure that no woman is ignored and no child forgotten." The eleven maternities of the *Assistance publique* (the official agency of Parisian charity) took care of public confinements among the poor, the *Mairies* furnished obstetric assistance at home, free consultation centers for pregnancy were established everywhere, military ambulances carried women to the hospitals, *cantines maternelles* supplied meals to pregnant women, military allowances were given to the mothers of soldiers' children, a government maternity grant was established on June 13, 1913, and long debates have been held in the Academy of Medicine as to the hygiene of pregnant women working in munition factories. *La Mutualité maternelle*, with over 50 consultation centers in Paris and elsewhere, insured the payment of 12 francs a week to mothers and 10 francs if they nurse the child. Senator Paul Strauss's law of August, 1914, allocates 1 franc daily to a prospective mother for a month before the birth of her child and 1½ francs daily for four weeks after, which has increased the birth rate. In 1915–16, 95.2 per cent. of all labor cases were cared for by the *Assistance publique* (Pinard) and the birth rate in this period was little more than half of that in 1913–14. The rates of infant and maternal mortality and of still-births fell in 1914–15 and rose in 1915–16, along with the number of abandoned infants, which Pinard explains by the increased employment of women in munition and other factories. Eventually, the French infants were cared for in wards attached to the munition factories, and the working mothers were allowed to nurse them at intervals. With a deficiency of 25 to 50 per cent. of physicians in the larger cities, with 800,000 women employed in munition factories, with an infant mortality rate of 126 in 1917, and with a war birth rate 50 per cent. less than normal and at least 40 per cent. below the total death rate, it became obvious that France was facing national extinction. During the whole period of the war, the discussion of the high infant mortality and the low birth rate went on in the Academy of Medicine, Pinard taking a strong stand against the employment of women as munition workers. In July, 1917, the Children's Bureau of the American Red Cross began its activities with eleven members under the direction of William Palmer **Lucas**; by July, 1918, it had over 400 members and its activities extended over the whole area of France. In the Toul sector, J. P. Sedgwick soon installed a colony of over 500 mothers and children and established a children's hospital of 200 beds, with chains of dispensaries in the smaller towns. This idea was carried through the whole war zone under the direction of Maynard Ladd, and, in Paris, the dispensary service was established by J. A. Miller. At Évian, where a contagious diseases hospital of 200 beds was established under C. F. Gelston, over 40,000 children of *rapatriés* were examined and treated, with dispensary service. At Lyons, a dispensary, hospital and barracks for refugee children were established, and a baby-show exposition, attended by over 170,000 people, was held on April 9 and three weeks after, under the direction of C. J. Grulee and, later, of Miss Ellen C. Babbitt. In June, this exhibit was transferred to Marseilles, and extended to other cities. The *guignol*, the cinema, cartoons, posters and picture post-cards were freely used, and a special educational bureau endeavored to reach the public through pamphleteering and the press. Special supplemental lunches for school children were developed by Mason Knox and Manning.†

* See Great Britain. Local Government Board. Maternity and Child Welfare. (Circulars, regulations and memoranda.) London (1916).

† See: Lucas, W. P., Jour. Am. Med. Assoc., Chicago, lxxii (1918), pp. 359–362; Am. Jour. Dis. Child., Chicago, xvi (1918), pp. 212–219. Grulee (C. G.), Am. Jour. Dis. Child., Chicago, xvi (1918), pp. 220–225. Knox (J. M.), *Ibid.*, pp. 242–252.

In Belgium, William Palmer Lucas reported indications of a decrease in infant mortality rate in the large cities (except Mons), largely due to the canteens for feeding expectant and nursing mothers and infants under three.

In Germany, there was a falling off of over two million births during the first three years of the war, so that 40 per cent. fewer babies were born in 1916 than in 1913, as compared with the 11 per cent. fall in England; but while the infant death rate rose from 151 per 1,000 in 1913, to 164 per 1,000 in 1914, it was markedly reduced in 1915–16, and well kept down thereafter. Even in the early months of the war, it was not as high as in the dry, hot months of 1911 (192 per 1,000). In consequence of mobilization, there was a sudden interruption of infant welfare work in nearly all German towns. The doctors in charge were called to the colors for military duty, the welfare workers were taken for army nursing, and many infants' homes were turned into military hospitals. One-fourth of all the Hessian welfare centers were closed, and five out of fourteen in Cologne. Even mothers frequently neglected their infants during this exciting period. In a letter of August 12, the Kaiserin pointed out the fatal error of neglecting infant welfare work for military considerations, but its revival was due to alarm over the sudden increase in infant mortality from August, 1914. The imperial allowances for soldiers' wives and children fixed by the law of August 4, 1914 were increased over four- and two-fold during the war, the maternity benefits under the Imperial Insurance Law of 1910 were liberally extended, a Federal Order authorizing imperial grants appeared on December 3, 1914, and was extended even to the wives of men on patriotic auxiliary service on July 6, 1917. There was a special grant for women who breast-fed their babies. By 1915, there were nearly 800 infant welfare associations in 550 localities, 271 day nurseries, and 266 maternal institutions, but in some localities these were entirely lacking. The Kaiserin Auguste Victoria Haus continued to be the center of infant welfare activities. Rickets and infantile diarrhea were alarmingly prevalent in 1915–16, and some physicians observed a special kind of war infants (*Kriegsneugeborene*), not premature, but under-developed at birth, with symptoms of constant restlessness and automatic grasping movements.*

In Canada, much has been done by Baby Week campaigning and the care of dependents of enlisted men. The valuable work of Miss Helen MacMurchy in Toronto has already been mentioned. Many of the Victorian Order of Nurses went for duty overseas. Of American pediatrists, Knox, Sedgwick, Lucas, Veeder, Ladd, Grulee, Manning and others were active in infant welfare work in the war zones.

It has now been attempted to give an outline of the history of pediatrics from its earliest beginnings to the present hour. If the exigencies of military duty have not permitted as exhaustive a study as might otherwise have been undertaken, I trust that enough has at least been presented to show the tremendous growth and importance of the science in recent years. Perhaps, like the infant itself, the subject of pediatrics first began to attract the attention of physicians through its very helplessness. No less than fifteen army surgeons mentioned in these pages have done much to forward this science, and the large number of pediatrists who have taken up infant welfare work in the present war goes to show the truth of Langstein's observation that "children are to be regarded as the most valuable capital of the state." This was, in fact, the view of the earlier German publicists, Süssmilch and Peter Frank.

Our bead-roll of benefactors of child-life includes Hippocrates, the founder of internal medicine and of infantile orthopedics; Soranus, who wrote the first individualized treatise on infant hygiene; Archbishop Datheus of Milan, who originated the foundling asylum; St. Vincent de Paul, the patron of friendless children, whose charitable endeavors led to the foundation of the *Hospice des enfants trouvés* (1640); George Armstrong, who founded the first dispensary for children (1769); Johann Peter Frank, the pioneer of school hygiene (1779); Count Rumford, who originated school lunches for children (1792); John Bunnell Davis, who adumbrated the modern methods of lowering the mortality of infants (1817); Morel de Villiers, Benjamin Broadbent and S. G. H. Moore, of Huddersfield, and Sir Arthur Newsholme, who made them accomplished fact; Semmelweis and Credé, who made the prevention of puerperal septicemia and infantile conjunctivitis viable; Théophile Roussel, the physician-legislator, whose beneficent laws for the protection of children have been our models; O'Dwyer, the inventor of intubation; Roux and von Behring, the discoverers of antitoxin; Grancher, the originator of isolation cubicles and of surgical cleanliness in children's wards in hospitals; Soxhlet, Rotch, Coit, Schlossmann and others who have made "clean milk" possible; the many investigators of infant nutrition and metabolism; and the great humanistic pediatrists, like Charles West, Jacobi and J. Lewis Smith, who have practised this branch of medicine, not merely as a scientific specialty, but from genuine love of the children themselves. Nor should we forget the artists, the musicians, the poets and men of letters who have added such a warm human interest to child-study.

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* Infant Welfare in Germany during the War. Report prepared in the Intelligence Department of the Local Government Board, London, 1918.

Contrast the utterances of the past, which meted out nothing to childhood but a frown of disapproval, with the larger, more tolerant attitude of modern writers:

"It is better to keep children to their duty by a sense of honor and by kindness than by fear of punishment." Tertullian.

"Nothing has a better influence on children than praise." Sir Philip Sidney.

"I would not have children much beaten for their faults, because I would not have them think bodily pain the greater punishment." Locke.

"Children are very nice observers, and they will often perceive your slightest defects. In general, those who govern children forgive nothing in them, but everything in themselves." Fenelon.

"Dispel not the happy illusions of childhood." Goethe.

"Where on earth is there so much society as in a beloved child?" Landor.

"Children have more need of models than of critics." Joubert.

"Do not try to produce an ideal child; it would find unfitness in the world." Hebert Spencer.

"The vilest abortionist is he who attempts to mould a child's character." Bernard Shaw.

"The best brought up children are those who have seen their parents as they are. Hypocrisy is not the parent's first duty." Bernard Shaw.

"Not one book in a thousand is worth as much to mankind as an innocent little child or a Chicago ham." H. L. Mencken.

In conclusion, I wish to acknowledge the generous and valuable assistance which has been rendered me by some of the most eminent pediatrists in this country, whom I have approached in the spirit advocated by a prominent writer on child-study: "Only the sham knows everything: the trained man understands how little the mind of any individual may grasp, and how many must coöperate in order to explain the very simplest things."* My correspondence with these gentlemen has been truly delightful and from their expressions about one another, I may (in the droll expression of Stendhal) "augur" the existence of a larger degree of fraternal feeling than exists in some other branches of medicine. Such followers of the pediatric art and science as I have known have seemed, for the most part, genial, helpful, unassuming men, men inclined to minimize their own talents, a trait rare in physicians, although the chief end of pediatrics is the maintenance of the family and the perpetuation of the human race.

* Gross, Hans.

CHAPTER II

CONGENITAL AND ACQUIRED PREDISPOSITION AND HEREDITY

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I. INTRODUCTION

The last twenty years have witnessed the birth and vigorous growth of the experimental investigation of the phenomena of inheritance. The field has proved so fertile that even those who are engaged actively in this research have found it difficult to keep track of the immense array of facts which has sprung up.

It is not surprising, therefore, that in the past geneticists have not made any considerable effort to present the more important discoveries in their science to workers in the allied sciences. Until lately they have been classifying and analyzing the data obtained by the numerous investigators in their own field. Now, however, has come the opportunity, and indeed the obligation to consider the bearing of the main discoveries in enegtics upon anthropology, agriculture, and medicine, and to visualize, even though it be imperfectly, the opportunity for coöperation and mutual gain in the bringing to the attention of investigators or practitioners in these fields the particular discoveries in genetics which should prove of immediate and permanent interest in their work.

Various factors such as slow breeding, and relatively small families have proved handicaps in the study of human genetics. Yet a notable array of facts have been obtained from investigation in this field, and these together with the results of breeding experiments with plants and lower animals have pointed to the conclusion that closer coöperation and mutual understanding between genetics and medicine is now a natural relationship which must be brought about.

The great majority of genetic discoveries have been made since 1900. Their recognition and appreciation will gradually lead to the adoption by medical men in general and by obstetricians and pediatricians in particular of a biological point of view which will aid immensely in reducing to an analyzable and predictable condition data that would otherwise remain unexplained and devoid of significance. Thus medical men must be made aware of the chief facts and discoveries resulting from genetic investigation in such subjects as sex determination, the physical basis of heredity, and the method of inheritance of normal and pathological, physical and mental traits in the lower animals and in man.

In a similar fashion geneticists will gain new inspiration and make great progress by utilizing the material which medical men can place at their disposal. The fields of comparative embryology, comparative pathology, bacteriology, physiology, psychiatry, immunology, pediatrics, and most other branches of the medical sciences are rich with problems for biologists and geneticists. The benefits which will result from coöperation between genetics and medicine are therefore mutual, important, and immediate.

To convince medical men of this, however, it will be necessary to place before them the more striking discoveries of genetics, to explain their value to medical practice and research, and to point out the ways in which medical men with a biological point of view thus established can and will provide a great body of trained observers and investigators who will continually add in an accurate and logical way to our knowledge of human heredity.

In no other way can the study of human heredity be so successfully pursued and be made of permanent value and of self perpetuating and ever increasing extent and interest.

In this chapter therefore, we shall consider in some detail the more important discoveries in the general field of experimental genetics; we shall then deal with the particular phase of human inheritance, and lastly, we shall consider the practical and utilizable value of the results already obtained.

In treating these subjects, the attitude taken may, at some points, seem to be dogmatic. In such event the reader is asked to remember that what we are striving for is a *point of view*, *a mental attitude*, and that therefore apparently radical statements must be taken on trust, later to be modified and limited, if necessary, by a more thorough investigation of all the points in question which is certain to follow the adoption of the viewpoint desired.

Genetics is young, vigorous, and perhaps in certain respects, over enthusiastic, but it has won its spurs and proven its worth biologically. It will moreover, provide a biological approach to many of the questions most interesting to medical men.

The pediatrician is in a peculiarly strong position in respect to the material with which he works. The child, although complicated, is not so much the product of environmental factors, as is the adult with the accumulation of years of training and artificial influences. The child is far more a product of purely biological factors and less a combination of biology and sociology, inseparably and confusingly interwoven.

This fact has been but little recognized by students of human inheritance who have expended by far the greater part of their efforts and energies in the investigation and analysis of the inheritance of adult traits. We may therefore, expect a surer and more rapid return from a study of the child, than from that of the adult, and we may hope that the pediatrician will be among the first of the medical profession to see the value of, and grasp the opportunities of a genetic point of view.

Illustrations and facts will be presented based on investigations with adult humans and with lower animals or even plants. As they are taken up, however, it should become clear that the facts of variation and inheritance have a common origin and behavior in high and low forms. Once this is perceived and recognized the data of many investigators become available to guide and to assist in outlining the genetic phases of medicine in general, and of pediatrics in particular.

If then this chapter assists the reader in obtaining a biological viewpoint and stimulates him to adopt an inquiring and coöperative attitude towards the genetic nature of his material—it will have amply justified its existence, and will have gone far towards giving inheritance its rightful place in a system of pediatrics.

II. DISTINCTION BETWEEN TRANSMISSION AND HEREDITY

One of the first points to be made clear is just what facts or categories of phenomena are to be included under our definition of heredity.

Broadly speaking, any substance or any characters developing from any substance passed by one generation to another may be considered as inherited. It is possible, however, at the outset to draw a distinction between substance actually transmitted as so much baggage by the germ cells such as the organism for syphilis on one hand, and the inherent parts of the biochemical constituents of the germ cell which are the underlying causative determinants of the truly genetic characters of the organism.

We shall therefore, consider as merely *transmitted* substances or bodies carried as passengers by the germ cell from one generation to another. Such materials do not react in any measurable or recognizable way upon the cells which carry them, but retain their distinct and characteristic form. Their presence or absence in any germ cell is due to their being placed there bodily by some definite physical process—such as infection, inoculation or through the medium of the blood stream. They are normally substances or bodies capable of independent existence outside of the germ plasm—in the form in which they are transmitted.

In this respect, they form a marked contrast with the truly hereditary factors or determinants which are an essential part of the cell organization and which are or have been up to the present time inseparable from it. These determinants appear to be highly specific in nature and in many cases complicated in structure. As will be seen, later, the analysis and prediction of genetic results on the hypothesis of the existence, the unit nature, and the definite position within the cell of such determinants have been the chief lines of progress in experimental genetics during the past twenty years.

We may then consider the behavior of a transmissable character in slightly more detail, in order to contrast it later with examples of true inheritance.

In this connection the experiments of Riddle, the Gages, and others, with the dye Sudan III are of interest. Sudan III is a dye which stains fatty tissue red. It becomes attached to fatty particles within the body and remains with them wherever they go. It follows therefore, that if and when the particles of fat pass through the follicular membranes and into the egg, they will, if they be stained with Sudan III, carry it with them and thus transfer it to the embryo. The simple and mechanical nature of this process as well as its distinction from what we ordinarily consider as inheritance has been recognized and pointed out by Riddle (1910) in the fowl as follows:

". . . While in the body, Sudan III clings at all times to the fats or their constituent fatty acids, and so goes quite mechanically wherever these particles go; it is indeed attached to them." And again:

". . . Within the ovum the Sudan III is deposited in the germinal disc and in the latebra in smaller amounts than elsewhere. This is undoubtedly to be associated with the lower fat content of these regions of the egg."

"If now one compares and contrasts these processes with those known to accompany inheritance; *i.e.*, developmental processes, some interesting features appear. There is, to be sure, *transmission* of the dye from soma to germ; there is a *persistence* of that which is transmitted to such an extent as to cause the soma obviously to display the "new character." If the body fat in the chick were used up in egg production as was elsewhere noted, some of the dye would of necessity again be deposited in the several eggs next formed; these eggs would in turn supply the somatic tissues developing from them. *But this must inevitably come to an end in a few generations;* the stain sooner or later will become diluted to the vanishing point. Again *there is absolutely no growth of the material* forming the "character," nor is there any chemical change either in early or in late phases of the life cycle."

We have then in such a case as this, the simplest type of a transmissible character which is carried into the germ cell but which remains chemically unchanged and a passive agent until so diluted by purely mechanical distribution that it does not *visibly* express its presence.

Very similar to this case is that of so-called "hereditary" syphilis. Here the syphilis organism is the actual material handed on from parent to offspring. In cases where successful transmission from parent to offspring takes place through an uninfected parent, the organism is borne as a passenger by the sex cells of the affected parent. Following its usual habit, the organism multiplies in the tissue in which it finds itself with the result that the fetus is infected. If now the fetus matures and though suffering from the disease reaches birth and grows to sexual maturity, there is, entirely outside of the chance of contact infection, an opportunity for *its* germ cells in turn to actually *transmit* the organisms to an uninfected individual and so to repeat the process above outlined.

Of course, in such cases, germ cells might, and probably would be formed free from the syphilis organism, due to the mechanical nature of the process by which the organism is distributed through the tissues. It will be observed that there is obviously *no way of predicting what proportion if any of the germ cells of a given individual are going to carry the organism.* This is in marked contrast with true inheritance, the nature of which we shall later consider.

A moment's consideration will serve to make clear the points of similarity between these two cases. In the first place the materials transmitted retain their identity *without chemical change*, in the second place they are both transferred from soma to germ by a mechanical process, as an outside or foreign body and finally they persist and reappear *unmodified* in the somatic cells, of the next generation.

We may next consider a slightly different category of cases, namely those in which attempts have been made to modify the germ cells by external agents, either physical or chemical. Among the numerous efforts made along these lines two sets of experiments stand out clearly. The first of these is work with radium and the second is treatment with alcohol vapor.

A. Experiments with Radium.—The destructive effects of radium on living tissue as evidenced by its ability to inflict severe burns and its therapeutic value in the treatment of cancer, have long been of considerable interest to biologists. Because of its absorption by and influence on the cell and particularly the nucleus, radium has been used as a possible modifier of the germ cell.

Chief among the experimenters in this field, are the Hertwigs who have carried out an interesting series of crosses with different species of frogs and other cold-blooded, water-inhabiting animals.

The mechanical advantage of using for experimentation a form in which fertilization normally occurs outside the body after the liberation of both male and female sex cells into water, is very great. The sex cells can be easily reached for treatment, the number of eggs liberated is commonly very large and the course of development easy to observe. These factors have contributed to the success which has been obtained by the Hertwigs.

In general their results may be summarized as follows: The embryos resulting from fertilization between lightly treated sperm and a normal egg are malformed and abnormal in character. The same is true in the case of a slightly treated egg fertilized by a normal sperm. In the two cases there is little if any difference in the nature or extent of the abnormalities, provided the *dosage* of radium is the same in both.

If either the sperm or the egg is treated for a long time, and is then combined in fertilization with a normal germ cell, the result is most surprising. Instead of an increase of abnormalities and deformities the resulting embryo is small but *normal*, and its development is distinctly slow. Cytological investigations have shown that such embryos are parthenogenetic. The radiated germ cell takes no part in development beyond the actual process of fertilization and the nucleus of the normal germ cell becomes the sole participant in the processes of cell division.

Unfortunately no cases have been reported of breeding records of the abnormal individuals and we cannot therefore determine whether and in what degree the abnormalities will be transmitted to succeeding generations. The appearance of abnormalities following light treatment strongly suggests the results obtained with alcohol vapor by Stockard with guinea pigs—but the occurrence of parthenogenesis shows a type of effect not seen in the guinea-pig experiments. Radium, because of its selective action on the nucleus is of especial interest in attempting to modify the germ plasm. Its effects are undoubted, but a regular and predictable genetic behavior following modification of the germ plasm without weakening or partially destroying its reactions are still to be obtained.

B. Experiments with Alcohol.—Pearl has carried out an extensive series of experiments to study the effect of the inhalation of alcohol vapor on the progeny of the domestic fowl. Throughout his experiments he has carefully controlled his tests by a considerable number of untreated animals. He has compared the progeny of tests and of controls in respect to prenatal and postnatal mortality, occurrence of abnormalities, weight at hatching, adult weight, rate of growth, and total number of progeny obtained. In every character except the last, the treated animals gave a better breeding record than did the controls.

Pearl interprets this as meaning that there is a selective mortality of weaker germ cells, as a result of the alcoholization, thus producing a selected surviving class which represents zygotes formed from stronger germ cells only.

In support of this he cites an interesting experiment in which a control group of artificially incubated eggs was compared with groups of artificially incubated eggs which had been subjected to fumes caused by the daily evaporation of 40 c.c. of 95 per cent ethyl alcohol for one, two, and three weeks respectively. The mortality in the egg was then observed and the chicks of all lots marked, and subjected to rather poor brooding facilities to induce a relatively high proportion of absolute mortality. The result was as follows:

	Eggs set	Per cent. infertile	Per cent. dead 30 days after hatching	Prenatal deaths in per cent. of fertile eggs
Lot 1—Alcohol one week....	130	26.2	28.3	42.7
Lot 2—Alcohol two weeks...	130	26.9	21.2	43.2
Controls..................	390	28.5	34.1	38.7
Lot 3—Alcohol three weeks.	130	32.3	37.5	60.5

It will be observed that the similarity of the four lots of eggs as regards the percentage of infertility is marked. The higher prenatal mortality of the alcoholics is also clear. When, however, we consider the postnatal mortality of the alcoholics and controls, we find that the former are of two sorts. Thus lots one and two have had sufficient alcohol to eliminate the weaker individuals and retain the stronger, while lot three has had so much exposure to the vapor that it consists of weakened individuals which are slightly poorer even in postnatal life than were the controls.

This experiment forms a strong support for Pearl's belief that alcoholization results in a selective mortality and a resulting superiority on the part of the *surviving* individuals in the alcoholized groups.

The general summary of Pearl's data is given in one of his 1917 papers and is in part as follows:

	Treated ♂♂ × untreated ♀♀	Treated ♂♂ × treated ♀♀	All treated parents	Untreated controls	Net result on alcohol offspring
Per cent. of infertile eggs, *i.e.*, in which no embryos were formed	25.2	59.2	41.7	25.3	−
Per cent. of embryos dying in shell	36.6	26.9	33.3	42.2	+
Per cent. of fertile eggs which hatched	63.0	72.3	66.7	57.8	+
Per cent. of all eggs which hatched	47.1	29.4	38.6	44.4	−
Per cent. mortality under 180 days of age	21.1	10.6	17.6	36.9	+
Per cent. mortality over 180 days of age	5.9	13.6	10.3	15.3	+
Mean hatching weight per bird ♂♂	34.91	36.97	....	34.24	+
Mean hatching weight per bird ♀♀	35.04	37.17	....	34.73	+
Mean adult weight per bird ♂♂	26.69	28.15	....	23.92	+
Mean adult weight per bird ♀♀	20.20	20.63	....	19.28	+
Per cent. of weak and deformed chicks	0.7	0	0.4	1.0	+

It is therefore apparent from the above table that alcoholization has resulted in a stringent elimination of the weakest, *i.e.*, the most susceptible germ cells, and further that these germ cells which have been eliminated would, if they had survived, have formed inferior zygotes from the point of view of every character measured. Alcohol then becomes a selective agent which by wiping out the weaker germ cells, especially the eggs, has decreased the *total* number of young produced but left physically healthier and more vigorous offspring. Whether the conclusions reached are applicable to mental traits is still a matter of doubt but so far as the physical traits of the fowl studied are concerned, the results are strikingly clear.

Much the same results have been obtained by Nice, following the alcoholization of mice. His experiments included administration of alcohol by two methods, an earlier series in which the alcohol was given with the food and a later series using an inhalation method similar to that employed by Pearl. Since the two series gave qualitatively like results, we may, for the sake of consistency confine our attention to the inhalation experiments. Four series of 11 weeks old mice were used. Each series consisted of three males and six females and were as follows: Control—untreated, male alcoholized, female alcoholized, and both male and female alcoholized. These groups together with a second generation from alcoholized parents, were compared in respect to early mortality, fecundity, and growth as measured by increase in body weight. The results may be tabulated as follows:

EARLY MORTALITY

	Total	Died	Per cent. which died
Control	47	0	0.0
♂ Alcoholic	66	4	6.0±1.91
♀ Alcoholic	41	4	9.8±2.99
Both alcoholic	73	5	6.8±1.91
Second generation alcoholic	25	1	4.0±2.6

It will be observed that there is more early mortality among the alcoholized groups than in the control. It is however, a question as to whether this fact has a real significance for if the chance deviation as expressed by the probable errors are taken into account it will be seen that even without a calculated deviation for the controls the differences between it and any of the alcoholic groups is scarcely three times the probable error. If a single one of the 47 control animals had died, not one of the differences between the control series and any of the alcoholic groups would have been significant.

In the case of fecundity it will be seen that the difference between controls and alcoholics is more marked. The fact that the various groups were under observation for different periods makes direct comparison difficult.

FECUNDITY

	Average young per litter	Average number of total young	Months under observation
Control	5.1	6.5	7
♂ Alcoholic	6.6	11.0	7
♀ Alcoholic	6.83	10.25	4
Both alcoholic	6.5	9.3	4
Second generation alcoholic	8.3	8.3	2

Commenting on these results Nice states that "The female alcohol mice show the greatest fecundity of all the lines while the double alcohol and second generation of alcohol mice come next." This is an interesting contrast to the results obtained by Pearl (page 177), when the total progeny is considered. It is however, quite probable that the difference is only superficial for if a selective elimination of eggs *within the ovary took place before ovulation*, the average number of young born would become more directly comparable to Pearl's category of "Percentage of fertile eggs which hatched," and in this group it will be remembered that the alcoholized fowl were superior.

Finally as regards growth within the various groups Nice found that although there was a certain amount of overlapping and crisscrossing at the first part of the curves, they later became more characteristic and at the eighth week the weights stood in the following order: Second generation alcohol 15.1 gm., female alcoholic 14.3 gm., male alcoholic 13.6 gm., double alcoholics, 13.0 gm., controls 11.6 gm.

There were no still births, abortions, and no monsters obtained. In closing, Nice points out that mice are very resistant animals and behave quite differently under alcoholization from guinea pigs, experiments on which we may next consider.

Stockard and Papanicolau have carried out an extensive series of experiments in an attempt to modify the germ cells of guinea pigs. Their work has stretched over a period of several years, and has yielded many interesting results. Certain points such as the heterogeneous and mixed nature of the strains and races of guinea pigs used by them are of course sources of trouble in generalizing from their data. However, inasmuch as their work provides practically the only evidence of positive influence of alcohol on the germ plasm it will be considered in some detail.

Their first extensive paper published in 1913 demonstrates that an effect of the alcohol can be transmitted through the parent to the offspring and by them in turn to another generation of descendants. Although the figures are not reduced to a basis of percentage and though no probable errors are calculated, it seems certain that the given data show that alcoholic animals are significantly worse than the controls as regards negative results of matings and early abortions, stillborn litters, number of living litters, and young dying soon after birth. What holds for the immediate progeny of treated animals also seems to apply to the next generation as well.

This is of course, *striking*, and is characterized by Stockard as the initial experimental evidence "*that an injury of the germ cell may express* its effects on the offspring and be passed through subsequent generations." It is interesting to note that Stockard considers the effect produced as "an injury." This appears to be significant, and will later be referred to when we consider just how far transmission rather than heredity is involved, in the handing on of the defects.

In his conclusion of this earlier paper he states "The poison injures the cells and tissues of the body, the germ cells as well as other cells, and the offspring derived from the weakened or affected germ cells have all of their bodies defective, both soma and germ, since each of the cells is a descendant of the injured germ cell combination. In this manner, the defects or degenerate conditions are transmitted or passed to subsequent generations."

It is however, entirely conceivable that a normal cell might arise from a combination of two abnormal ones, and that the truth of the extent of the modification or injury process may really lie somewhere near but slightly below the complete and absolute degree of modification which Stockard suggests. Furthermore, different individual germ cells are undoubtedly subjected to different degrees of injury by being more or less resistant because of age, or physiological condition, or contact with different concentrations of the injurious substance. This would result in the presence of different degrees of abnormality from perhaps unrecognizable modifications to complete inactivation. The logical sequence to this would be the disappearance of slight grades of the injury in some or perhaps all descendants of certain of the most lightly affected animals.

In 1916, Stockard, in collaboration with Papanicalou, published a further analysis of what they have termed the "hereditary transmission of degeneracy and deformities."

Much of this paper consists of an effort to demonstrate a differential effect on the sexes. This question will be brought up again later when we consider sex. In the meanwhile it will suffice to say that much of the evidence which they believe to be significant does not stand the test of mathematical analysis, of the most elementary sort, The increased numbers, however, add weight and conviction to their *general* tenet *and show beyond reasonable doubt that they have obtained a transmission of injured germ plasm for more than one generation.*

Thus a summary of the different matings may be constructed from the table given in the 1916 paper, on page 77.

The three bottom lines of this table give an interesting test of the differences existing between the three lines. Those in which one or both parents were alcoholized and those whose grandparents or great grandparents only were alcoholized resemble each other. The latter category shows if anything greater mortality than the former. This is striking for the immediate administration of alcohol is two or three generations removed. Both of these alcoholized groups are significantly different from the normal control group as the following comparison will show.

The difference in percentage of surviving young from control and parental alcohol lines is 35.9 ± 3.22. This difference is 11.14 times its probable error and is certainly significant. It is much the same when the record from second and third generation alcoholics as compared with the controls. In this case the difference in percentage is 40.3 ± 3.41, or 11.79 times its probable error.

These two results establish beyond any doubt that there is a significant difference between the progeny of controls and alcoholics in respect to early mortality. Without entering into a detailed analysis of the data, it may be added that the same relationship holds good for structural abnormalities and deformities. The alcoholic lines are significantly inferior in these respects when compared with the controls.

In their 1918 paper the same authors bring certain other criteria under consideration. These include average litter size, the number of oversized individuals and the number of undersized individuals.

The average litter size of the normal lines is 2.77 young, and of the

Mating	Number of matings	Negative results, early abortions	Per cent. negative	Still-born litters	Living litters	Young dying soon after birth	Total dead	Surviving young	Per cent. of young surviving
Alc. ♂ × Norm. ♀	90	37	41.1 ±3.5	10	43	35	55	47	46.0
Nor. ♂ × Alc. ♀	33	7	21.2	4	22	23	35	21	37.4
Alc. ♂ × Alc. ♀	41	20	48.8 ±6.6	4	17	12	20	14	41.1
Total	164	64	39.0	18	82	70	110	82	42.7 ±2.35
Control	90	22	24.4	2	66	19	27	99	78.6 ±2.43
Second and third generation from alcoholics crossed inter se	176	64	84.2	18	94	78	116	72	38.3 ±2.4

alcoholic lines, 2.47 young. The difference between them is 3.5 times its probable error and is therefore probably significant.

The percentage of oversized individuals in normal lines is 5.58 and in alcoholic lines 2.86. The difference in this case is *not* significant. On the other hand, the percentage of undersized individuals in normal lines is 0.42 and in alcoholic lines 1.34. Here the difference between the lines is great enough to be probably significant.

The authors gave two very interesting tables of comparison in the later paper. The first of these consists of the breeding records of certain normal individuals crossed first with normal males and then with alcoholic males. The results are shown herewith.

	14 normal males mated successively with:		15 normal females mated successively with:	
	Normal ♀♀	Alcoholic ♀♀	Normal ♂♂	Alcoholic ♂♂
No. of matings	36	44	26	23
Total young	86	100	59	50
Negative result	2	4	1	5
	(5.55%)	(9.09%)	(3.84%)	(21.73%)
Lived over three months	65	58	51	30
Dead within three months	21	42	8	20
	(24.41%)	(42.0%)	(13.55%)	(40.0%)
Defective	0	6	0	5
		(6.0%)		(10.0%)

This is a striking result and shows a consistently poorer record by alcoholics. The second table is a comparison somewhat similar to that of Pearl's of normal and alcoholic lines in respect to the characters studied. It is found on page 209 of Stockard's and Papanicalou's 1918 paper and is, in part, as follows:

Qualities measured	Normal	Alcoholic	Alc. superior + Alc. inferior –
Size of litter	2.77	2.47	–
Failure to conceive	4.45%	13.04%	–
Early prenatal death	Low	High	–
Proportion late prenatal death	51.92%	70.14%	–
Postnatal mortality	10.70%	10.60%	0
Total mortality	22.31%	35.52%	–
Abnormalities	0	2.52%	–
Undersize	0.42%	1.34%	–
Average birth weight of litter	197.12	170.0	–
Average birth weight of individual	77.16	70.35	–
Average weight one month	228.64	213.94	–
Average weight three months	425.11	404.13	–

The record of alcoholics is inferior in all the characters studied except post-natal mortality, in which case neither appears to have an advantage.

Although at first glance the results obtained respectively by Pearl, Nice, and Stockard, appear to be at variance, further consideration shows that such is not actually the case. There is no difficulty in explaining all results on a common ground if we assume that the material used by Pearl and Nice expresses its susceptibility to alcohol in the extremely early stages of ontogeny, or during gametogenesis and is far less susceptible if not entirely unaffected in the later stages. There is a sharper line of demarcation between the affected and the unaffected individuals, and the various grades of effects seen in guinea pigs are in fowl and mice all lumped into one class, resulting in the death and destruction of the germ cell. The result is, that in these forms there is a selection process which eliminates the weaker and malformed individuals thus producing an unusually healthy and fit population. In guinea pigs, on the other hand the effects are more variable and the appearance of undersized and deformed individuals as well as the high early post-natal mortality results in a weakened and unfit race.

If we now consider this work with alcohol and radium in relation to the behavior of Sudan III and of the syphilis organism we shall recognize that conditions are much more complex in the first named case than in the two last-named cases. The results from the alcoholization experiments approximate true inheritance much more closely than do those obtained with the syphilis organism or with Sudan III.

Yet there is even in the work with alcohol the feeling of a difference between its behavior and that of inheritance in the analyzable and predictable sense in which the last named process has come to be viewed.

Stockard in speaking of this matter in 1913 said, "Arguing from this analogy there must be *pathological* heredity due to diseased or altered chromosomes in the germ cell just as truly as there is a known pathological behavior of every other organ and tissue of body." It is clear that he had in mind the fact that the germ cell had been injured and had become pathological. This seems entirely probable and will be returned to once more when we have reviewed in some detail the behavior of truly inheritable characters.

While interesting and significant they all, up to the present, leave something to be desired as orderly, modifying agents. They *are invaders* of the cell rather than participants in its functions and they interfere in the cell mechanics and in the origin of normal daughter cells either by providing a foreign body or substance to go into the daughter cell or by disrupting the normal method of cell division.

III. GENERAL DEVELOPMENT OF GENETICS AS A SCIENCE

The broad foundation from which the science of genetics has been built up is the mass of information collected by Darwin and the adoption of an evolutionary point of view to which this led. With the adoption of an evolutionary point of view the need of explaining the processes of handing on resemblances from one generation to another became paramount.

The stimulus which Darwin's work gave to experimental biology and its all important rôle in the formative stages of the science of experimental genetics can be seen by considering briefly the development of that science from Darwin's time to the present with reference to the following matters:

(*a*) The relation of soma and germ plasm.
(*b*) The nature of genetic change.
(*c*) Practical methods of analysis.
(*d*) Recent advances.

A. THE RELATION OF SOMA TO GERM PLASM

Darwin postulated an intimate connection and relationship between soma and germ plasm. His theory of pangenesis provided a mechanism by which through the medium of the blood stream, it was possible for the hypothetical pangens—or tiny biological delegates from various parts of the soma to make their way to the germ cells and there affect the portion of the germ-cell which was to be responsible for the development of that particular part in the soma of the next generation.

It will be seen that this hypothesis was necessitated only by the supposition that germ cells were developed by the soma, and that effects of use and disuse of various parts of the soma led to changes which were faithfully reproduced by the pangens in the germ plasm.

Since as we shall see, this particular relationship between germ plasm and soma does not actually exist, there is no need of anything to explain a type of transmission from the soma to the germ, which has not been observed.

We may then discard the theory of pangenesis and similar efforts to provide a means for such transmission and consider briefly the contribution made by Weismann in clarifying the relation between germ plasm and soma.

Weismann showed that there was continuity of the germ plasm from one generation to the next and that somatic modifications such as mutilations did not leave any impression on the germ plasm and were therefore not inherited. By his view the germ plasm became essentially immortal and existed in an unbroken string from one generation to the next.

Furthermore his work led the investigators of that time to focus their attention upon the germ cells and upon the breeding behavior rather than upon the somatic appearance of the individual.

This change in point of view bore the most valuable and interesting fruit, for it lies at the foundation of experimental genetics and is the basis on which experiments, leading to considerable progress, have been made.

1. Non-inheritance of Acquired Characters.—During recent years abundant efforts have been made to obtain conclusive evidence on the inheritance of acquired characters. If we judge the characters studied, from a purely Lamarckian standpoint we are forced to conclude that the results of these efforts have been negative or inconclusive.

This as Conklin has pointed out is largely because the whole postulate of Larmarckian "acquired" characters is based upon a mistaken conception of the true relation between soma and germ plasm. This may be explained by the following diagram (Fig. 54) showing the correct and the incorrect conception of the relationship between germ cell and soma in sexually reproducing forms.

It will be noticed that the germ cell does not give rise to the soma and the soma in turn, to germ cells for a new generation. Rather it appears that germ cells give rise to two things a *soma and other germ cells*. It therefore becomes fairly clear that the idea of the transmission of modifying influences from the soma to germ cells which were being developed by it, is based upon a false premise as to the origin of the germ cells which are to be modified. Such a transmission of effects from soma to germ therefore becomes illogical and unnecessary. The problem changes to a question of how to modify future germ cells through influencing existing germ cells—their ancestors. This is a question far removed from Lamarck's conception of acquired characters and involves therefore an entirely different line of treatment and approach.

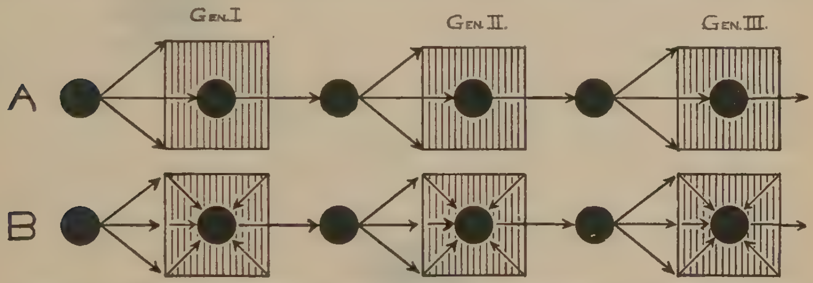

FIG. 54.—Diagram showing relationship of germ plasm (solid circles) to soma (shaded squares). A, correct relationship showing derivation of germ plasm from preexisting germ plasm (continuity of germ plasm). B, Incorrect relationship showing derivation of soma from germ and germ from soma.

Among the many experiments attempted we have in the persistent and transmissible effects of alcohol observed by Stockard and Papanicolau, already referred to, a possible case of modified germ plasm giving rise to modified soma and again to modified germ plasm.

The parallel between germ cells and cancer cells has been pointed out by Leo Loeb and the analogy leads to interesting comparisons. The cancer cell represents a departure of a marked and definite physiological nature from the usual conditions of normal controlled growth found within the tissue in which it arises. This change appears to be permanent and is handed on to the cell descendants faithfully and, so far as we know at present, in an unchanged condition. The environment of the abnormal cancerous tissue may be changed by transplantation to a new host. Here, however, if growth is possible, the old characters are maintained, and the cancerous tissue retains its identity and physiological independence.

The analogy between its behavior and that of the germ cells is extremely striking. There is a continuity between the "transplant" generations of cancer cells just as there is between the germ plasm of succeeding generations.

The permanency and constancy of the biological properties of tissues are obviously fundamental and this is true of all types of tissue. Nowhere is this more clearly seen than in chimeras among plants. Here a shoot has been given off exactly at a junction between a graft and its stock. In some such shoots one-half longitudinally is characteristic of the scion, and the other half of the stock, and this holds in the branches, leaves, flowers and fruit given off by the respective halves. In other cases, the outer layer of the shoot's tissues are like one parent, and the inner layer like the other. The point of interest to us at present, is the apparent jealousy with which each part guards its individuality and the ordinary failure of anything resembling a blend between them to appear.

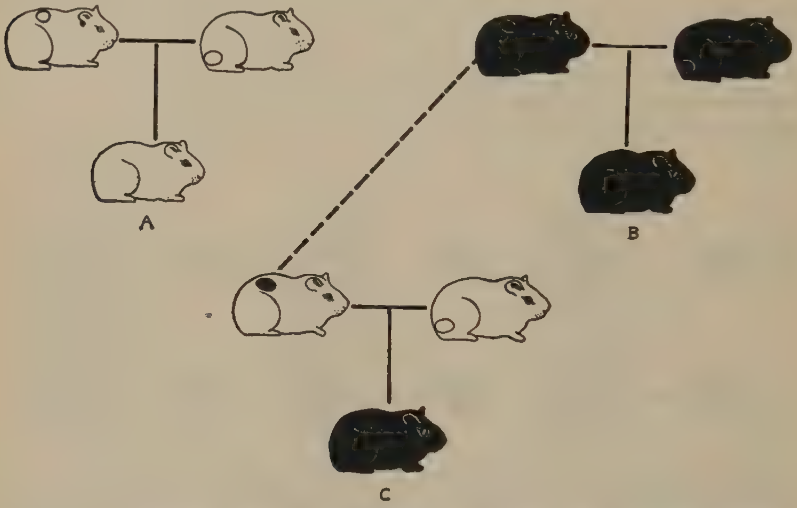

Fig. 55.—Diagram showing experiments of Castle and Phillips devised to indicate absence of foster mother influence. A, Two albino guinea-pigs giving only albino young. B, Two black guinea-pigs giving only black. C, Castrated albino guinea-pig, female, with implanted black ovary taken from black female (dotted lines) giving, when crossed with albino male, only black young.

There is no question that environment can greatly alter the nature of the soma by direct action. The effects of under nourishment, of feeding glandular extracts and of exercise are examples with which all medical men and biologists are familiar. What is not usually so clear, however, is the more important truth that the effects are not permanently impressed upon the germ plasm. This is because the germ plasm contained in the obviously modified soma is directly descended from other germ plasm which is free from the effects in question.

An interesting series of transplantation experiments by Castle and Phillips has shown the inability of the soma to influence the germ plasm, residing in it, in respect to coat-color characters in guinea pigs. It has been shown by a score of investigators that albino rodents including guinea pigs, breed true. That is to say, when two albino guinea pigs are bred together, their offspring have without known exception, been albinos. The same is true of certain races of colored guinea pigs. Animals from such races give only colored and never albino young. Castle and Phillips transferred the ovaries of a young guinea pig from such a colored race to the body cavity of a young albino guinea pig whose own ovaries had previously been removed. Their object was to determine whether the soma of the albino would affect the ability of the colored animal's ovary growing in it, to produce *only* colored offspring. They mated the albino containing the "colored" ovary with an albino male. In such a mating of "colored" with albino it was known from much previous work that if the transplanted colored ovary was uninfluenced by its albino foster mother, only colored young would result. This was indeed the case, none of the seven young produced being albinos. A similar result was obtained for two other types of coat-color pattern and the conclusion was inevitable that the transplanted ovaries were unmodified by their foster mother in so far as the color characters studied were concerned.

The conclusion can however, only include color characters and since these are known to be dependent upon enzyme action it is entirely possible that minute quantitative effects of the foster mother might have passed unnoticed. This necessarily follows since if the time given for enzyme action had been sufficient and the concentration of the enzymes unchanged, the end products, namely, the color produced, would have been the same even if the *quantitative* relations had been slightly modified.

The burden of proof that such quantitative changes or modifications *do* occur is, however, not theirs, and the evidence in so far as it goes supports the view that the hereditary properties of the transplanted ovaries are unaffected.

We may therefore sum up the evidence as to the inheritance of acquired characters in a Lamarckian sense, by saying that there is no evidence or expectation that modifications of the soma will be passed on to the germ cells and that therefore modification of the hereditary characteristics must come from affecting the germ cells themselves either alone or as a part of the soma since they and they alone are the ancestors of future germ cells.

B. Genetic Change

Having considered briefly the relationship between the germ plasm and the soma we may next examine what is known of the method and types of genetic change.

Darwin's views on these matters are familiar to all. The gradual and continuous nature of the processes underlying the origin and handing down of inherited modifications was featured by him and was considered of general application and of primary importance in the scheme of evolution as he saw it. He mentioned the occasional appearance of sudden abrupt changes giving rise to considerable modifications of structure, but believed them to be the exception and of secondary importance only.

This feeling that genetic change was due chiefly to minute steps, continuous and frequent, became a generally accepted doctrine and formed the basis for Galton's Law of Inheritance, and for the School of Biometricians which developed during the last part of the nineteenth century. The idea remained in ascendancy until De Vries in 1900 published his work on the "Mutationstheorie."

In his work he recorded among other things, extensive experiments with the evening primrose *Oenothera lamarckiana* and stated that he believed that species were formed by sudden abrupt changes which he called *mutations*. If these changes were then the chief agents in the formation of species, and species were in turn considered, the stepping stones of evolution, then it followed that these mutations or sudden changes of considerable extent were the chief means of evolution.

Coming as it did in the face of a well-established belief in minute gradual changes as the chief agents in evolution, the new theory met with a somewhat mixed reception. The rediscovery of the Mendelian principles occurring simultaneously, however, aided it considerably and it grew rapidly in favor.

The present feeling of a majority of geneticists would, I believe, be fairly expressed by stating that *evolution within the germ cell* occurs by definite steps and that these, representing changes or rearrangements of a physico-chemical nature within molecules, are of necessity, sudden and discontinuous.

If, as frequently happens, such a change produces as its direct effect a marked and distinct somatic modification it forms one of the true mutations of De Vries or "sports" of Darwin. If, on the other hand, the germinal change though just as distinct and definite in nature, affects to a far lesser degree the visible somatic characters, the *appearance* would be that of a minute "continuous" variation quite distinct from the more easily recognizable changes or mutations. Yet the underlying process in the germ cell might well be identical in size and importance in both cases.

It may therefore, be stated that the modern point of view of geneticists is more nearly De Vriesian than Darwinian, and that the question of chief interest is not how species are *formed*, but rather *what* is the nature of the genetic changes which modify the germ plasm and thus shape the rate and degree, if not the *course* of evolution.

C. METHODS OF ANALYSIS

In no respect perhaps has a greater advance been made since Darwin than in methods of analysis, of the data obtained in investigations of the nature of inheritance. The methods of analysis most in use may be classified under two main headings, as cytological, and Mendelian. It is not intended to suggest that the two methods are mutually exclusive. On the other hand, they tend to aid and support each other as will be seen shortly when examples of their application are considered.

1. Cytological.—Inasmuch as cytological investigations resulting in explaining the form and chemical makeup of the sex cells must be the eventual goal of experimental genetics it will be well to consider first the nature of this method of analysis. During this treatment of the subject, particular attention will be paid to the chromosomes since they have been demonstrated by Morgan and his associates to be the bearers of, or an intimate reflection and synopsis of many of the hereditary characters.

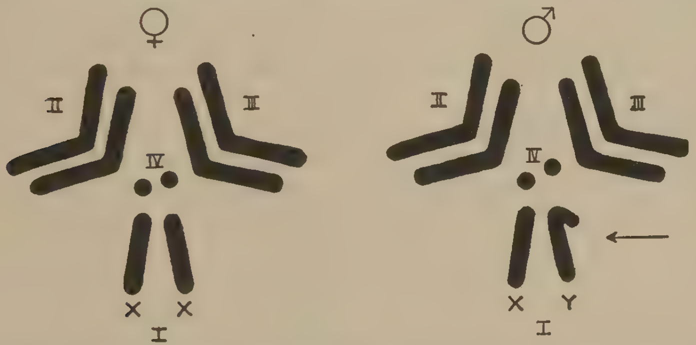

FIG. 56.—Diagrammatic representation of chromosomes of somatic cells of Drosophila Melanogaster, male and female. Note four pairs, I to IV, and the sex chromosomes, XX in the female; XY in the male.

The number of chromosomes in the somatic cells of an individual is, generally speaking, constant. It however, varies greatly and apparently fortuitously in different species. Thus the fruit fly *Drosophila melanogaster* with which Morgan has worked, has eight, another Drosophila (*buskii*) has 10, Dogs, 22; Rabbits, 24; Mice, 40; Man, 48; Peas, 14; and Corn, 10. These numbers have been determined after careful cytological investigation and in most cases by several investigators.

When the individual reaches sexual maturity and its testes or ovaries as the case may be, begin to mature the sex cells, a reduction in the chromosome number of the mature sex cell to one-half that of the number in the somatic cells takes place. It has been shown conclusively that in *Drosophila*, the eight somatic chromosomes are in reality four pairs, and that in reduction one of each pair goes to each germ cell. Furthermore, these pairs differ in size and shape as Fig. 3

shows diagrammatically, and retain their individuality throughout all the processes of cell division and reduction.

This principle of *individuality of the chromosomes* is, in all probability, general in its application and as will be seen shortly, is a phenomenon of considerable importance and significance. *The independence of the chromosomes, their individuality, and their reduced number in the sex cells are fundamental.* The sex cell with its reduced number of chromosomes is known as a *gamete.* When two such cells meet in fertilization a dual individual with the characteristic somatic number of chromosomes is synthesized and is known as a *zygote.* The individual as we commonly know it is then, from its origin, a double organization. Nowhere has this been more clearly demonstrated than in frogs developed by artificial means from unfertilized frog's eggs by Batallion, and by Loeb and Bancroft. The successful development of parthenogenetic individuals and their metamorphosis from tadpole to frog has shown that the ordinary vertebrate has a double organization which under certain conditions at least is not absolutely necessary to the life and development of an individual. We shall refer to this condition again when we consider the next great advance in methods of analysis.

2. Mendelism.—General Statement.—Gregor Mendel was an Austrian monk, a professor of mathematics at a monastery in Brünn. Being a botanist as well, he combined his knowledge in the two fields in an effort to discover and formulate a workable and predictable "law" of inheritance. In doing this, he showed extreme skill in his choice of material, originality, and brilliance in his methods of investigation, and logical, accurate and unassailable reasoning in his interpretation of his results. His short communications published in 1866, in an obscure journal remained unrecognized and buried until simultaneous, independent rediscovery in 1900, of the principles which he had recorded, by Correns, von Tschermak, and De Vries.

In certain of his experiments, Mendel used garden peas and in their study introduced an important new point of view. This consisted in focusing attention on *pairs of characters* in which well-established races differed. Thus for example, he had one race of peas which grew to a height of from six to seven feet (tall) and another race which grew only to from 18 to 24 inches (short). By breeding tests he knew that each of these races was breeding true in respect to the height character which they possessed. The tall plants gave only tall offspring, and the short plants, only short offspring. If now, we arbitrarily give to the tall and short characters, abbreviated symbols, *T* for tall, and *t* for short, and if we, knowing these characters to be inherited, remember that each individual plant is a dual structure or *zygote*, formed from the union of two germ cells or gametes, we may indicate an individual of the tall race as *TT*, and one of the short race as *tt*. The tall individuals will form germ cells with a *single* representation of *T* in each, the short individuals, germ cells with *t* in each.

When however, a tall individual and a short one are crossed together, we have in the hybrid a new combination resulting from a union of the T from the tall, and a t from the short parent. Theoretically, such a Tt plant might be expected to show one of three conditions. It might be (*a*) like the tall parent in appearance, or (*b*) like its short parent, or (*c*) a new form different from either. Actually in Mendel's experiments the first condition was realized, and the hybrids grew as tall or taller than their tall parents.

When now these first generation, or F_1 *hybrids* as they were called, were used for breeding the two great principles which Mendel discovered, came to light. The first of these was the principle of *segregation* in the hybrid germ cells, of the determinants for tallness and shortness. That is to say the hybrid Tt formed germ cells containing T *and* germ cells containing t, but *never germ cells with both* T *and* t, *or with neither*. Also in so far as it could be seen T and t were unchanged in character by their association in the same zygote. That is to say, they were not contaminated by one another nor blended together.

The second great principle; random recombination, was that gametes containing T and those with t were formed by the Tt individual in essentially equal numbers and were combined in fertilization purely according to the *law of chance*.

Bearing these two principles in mind, we may consider a diagram showing the crossing of two Tt, F_1 hybrids together.

Plants crossed	Tt = tall × Tt = tall	
Forms gametes	T and t T and t	
These by random recombination give zygotes in F_2 generation	1TT 2Tt	3 Tall
	1tt	1 Short

We have known, from the initial cross between TT and tt individuals, that Tt zygotes are tall in appearance, and we should therefore expect a ratio of three tall to one short in the second hybrid or F_2 *generation*. This ratio was closely approximated in Mendel's own work, and has been demonstrated conclusively by other investigators who have repeated the cross.

Examination of the four classes of individuals comprising the F_2 generation shows that the short character which disappeared in the F_1 generation has reappeared. Furthermore, while the short individuals are all tt in composition, the tall individuals are of two sorts. One of the three is TT in composition, exactly resembling the tall grandparent which because its composition in respect to T is uniform, can be called *homozygous*. The other two are Tt in formula resembling their hybrid tall parents, and are called *heterozygous*.

Breeding tests of the tall individuals in F_2 have shown that these two types actually exist in approximately a 1:2 ratio. The test made was to cross tall individuals with short plants. When this is done, the two types give strikingly different results as follows:

	(*a*) F_2	(*b*) F_2
Plants crossed	*TT* tall × *tt* = short	*Tt* tall × *tt* short
Forms gametes	all *T* all *t*	*T* and *t* all *t*
By random recombination forms zygotes	All *Tt* = tall	*Tt* } = 1 tall *tt* } = 1 short

The tall character which has appeared in the F_1 generation to the exclusion of the short is known as the *dominant* character, and the short character which has been suppressed and later reappears in the F_2 generation is known as the *recessive* character.

Many other characters in peas were found by Mendel to give similar alternative results in inheritance, for example: color of cotyledons and seed coats, form of seed, form of pod, and position of flowers.

Relations between the two members of a pair of characters are not always so simple. For example, Andalusian fowls occur in three color types, black, blue, and white-splashed. The white-splashed birds are almost entirely white with only an occasional black or blue feather. When two such white-splashed birds are bred together, they produce only white-splashed young. Similarly when two blacks are crossed together, only black young are produced. When blues are crossed together, all three types are produced in a ratio of one black, to two blue, to one splashed white. Finally when blacks are crossed with splashed whites, *only blue young are produced.*

The whole case is explicable as one of mendelian inheritance as follows: black are homozygous *BB*, white-splashed are homozygous *WW*, but the heterozygous *BW* form shows neither dominance of black, nor of white-splashed, but is "blue" or intermediate in color. Thus:

Birds crossed	*BB* = black × *WW* = white-splashed
Forms gametes	All *B* All *W*
By random recombination forms F_1 zygotes	All *BW* = blue
	Two such blues are crossed with the following results
Birds crossed	*BW* = blue × *BW* = blue
Forms gametes	*B* and *W* *B* and *W*
By random recombination forms F_2 zygotes	*BB* } 1 black 2*BW* } 2 blue *WW* } 1 white-splashed.

The mendelian principles of the unmodifiability of the determinants *B* and *W* and of the segregation and chance recombination of them in the germ cells of hybrids hold good.

When more than one pair of mendelian characters are being studied, in the same cross, it is usually found that they are entirely independent from one another in segregation and recombination, as follows:

In guinea pigs there is besides the ordinary short-haired variety seen commonly in the laboratory, a long-haired or "angora" variety. These two types of coats are a pair of mendelian characters, alternative in inheritance. Short hair is dominant over long hair. Entirely distinct and independent from these, is another pair of characters—colored coat, and albino coat. These also are mendelian, with colored coat dominant, and albino recessive.

If a colored short-haired individual *CCSS* is crossed with an albino long haired animal *ccss*, the first generation are all colored and short-haired as follows:

Animals crossed	Colored short-haired	×	White long-haired
	CC SS		*cc ss*
Gametes	all *CS*		all *cs*
Zygotes	all *CcSs*	Colored short-haired, carrying albino and long-haired as recessives.	

When now, these hybrid colored short-haired animals form germ cells, the two pairs of characters segregate independently of one another with one of each pair in each gamete.

Animals crossed	F_1 Colored short	×	F_1 Colored short
	Cc Ss		*Cc Ss*
Gametes	*CS*		*CS*
	Cs		*Cs*
	cS		*cS*
	cs		*cs*

Zygotes in F_2

CS *CS*	*CS* *Cs*	*CS* *cS*	*CS* *cs*
Cs *CS*	*Cs* *Cs*	*Cs* *cS*	*Cs* *cs*
cS *CS*	*cS* *Cs*	*cS* *cS*	*cS* *cs*
cs *CS*	*cs* *Cs*	*cs* *cS*	*cs* *cs*

Each square is a zygote, the 16 squares representing the possible recombinations of the two pairs of characters in question.

By carefully studying the constitution of the F_2 generation animals, their various genetic characteristics will be made clear. Tests of the constitutions of these animals were made practically by breeding them back to the albino long-haired race. Their various genetic capacities will then become apparent. Examples of tests of the four F_2 types of black short-haired animals follow:

1. Black short Albino long $CC\ SS$ × $cc\ ss$ Gametes CS cs Zygotes all $Cc\ Ss$ Black, Short. Tested animal homozygous for both short hair and color	2. Black short Albino long $Cc\ SS$ × $cc\ ss$ Gametes CS cs cS cs Zygotes 2 $Cc\ Ss$ Colored, short. 2 $cc\ Ss$ Albino, short. Tested animal homozygous for short hair heterozygous for color.
3. Black short Albino long $CC\ Ss$ × $cc\ ss$ Gametes CS cs Cs cs Zygotes 2 $Cc\ Ss$ Colored short. 2 $Cc\ ss$ Colored long. Tested animal homozygous for color, heterozygous for short hair.	4. Black short Albino long $CcSs$ × $cc\ ss$ Gametes CS cs Cs cs cS cs cs cs Zygotes 4 $Cc\ Ss$ Colored short 4 $Cc\ ss$ Colored long 4 $cc\ Ss$ Albino short 4 $cc\ ss$ Albino long Tested animal heterozygous for both color and short hair.

An extension of the principle governing crosses involving one or two pairs of mendelian characters or *allelomorphs* as they are called, can be made to include an indefinite number of pairs. *So far, however, the number of pairs of characters for any one species which are completely independent in inheritance have never been found to exceed the reduced or gametic number of chromosomes characteristic of the species.* If more pairs of mendelian characters exist than there are present gametic chromosomes, certain of them are linked in inheritance in varying degrees, thus forming groups in each of which the determinants carried are related in inheritance. This matter will be returned to when sex-linked inheritance is considered.

(*b*) **Multiple Allelomorphs.**—In the cases mentioned which we have just observed, there are *two* segregating and mendelizing conditions in each group, forming *an allelomorphic pair.* There are however several other well established cases where three or more conditions depend upon mutually allelomorphic determinants only *one* of which can go into each gamete.

In rabbits, for example, there is besides the completely albinic and fully colored types a third grade of pigmentation known to fanciers as Himalayan. In this variety, the nose, feet, ears, and tail are colored and all the rest of the animal is white. This Himalayan condition mendelizes with albinism, and is dominant to it. It also mendelizes with complete pigmentation and is recessive to it. For such a series, the term "triple allelomorphs" has been used. The important point is that a gamete can contain only one of the three determinants involved. The result is that only the following types of animals can be formed.

Symbols. C = Complete color C' = Himalayan and c = complete albinism.
CC = Colored homozygous
CC' = Colored carrying recessive Himalayan
Cc = Colored carrying recessive albinism
$C'C'$ = Himalayan homozygous
$C'c'$ = Himalayan carrying recessive albinism
cc = Albino homozygous.

A colored individual can carry C' *or* c as a recessive, but never *both*. In mice, four such characters are found in a single series of multiple allelomorphs representing different proportions of dark and yellow pigment in the coat. In cats, there appear to be one and possibly two such triple series; in dogs, possibly one; in rabbits probably three more besides the ones mentioned; in guinea pigs, a single series of five; in the fruit fly, Drosophila, a series of eight eye colors. In plants the phenomenon is fairly well known. We must therefore conclude that the condition is of general occurrence and importance.

(*c*) **Multiple Factors or Determinants.**—In the cases of Mendelism so far reviewed, we have found that the characters studied have apparently depended upon a single determinant or factor in the germ cells. Three important variations from this simple condition are found. They consist of: (1) Characters which may be produced by any or all of several supplementary factors; (2) Characters which are due to the simultaneous presence of several independent factors and (3) Characters whose variation is due not only to changes in the particular determinant which underlies that character, but also to other determinants or modifying factors independent of the main factor in inheritance but modifying its somatic manifestation by their presence.

As an example of characters which may be produced by any or all of several supplementary factors, we have Nilsson-Ehle's work on the inheritance of color in wheat. In this form, red color is dominant to white in crosses. In the F_2 generation however, while some of the families give a ratio of three red to one white, others give a clearly distinct ratio of 15 red to 1 white, and still others ratios of 63 red to 1 white. This is apparently due to the fact that there are three factors for red color, any one of which is sufficient to produce it. We may call these factors A, B, and C and assume that white is produced in plants lacking all of them and therefore abc in formula.

This being the case, the 3:1 ratio is produced in families, in which the difference between the red and white race is one involving only one of the factors A, B, or C. This may be shown in a single family as follows: Here we shall suppose that the factor C is the only one involved.

Plants crossed	Red	×	White
	aa bb CC		*aa bb cc*
Gametes	*abC*		*abc*
F_1 Zygotes	All *aa bb Cc*-Red.		

Plants crossed	F_1 Red	×	F_1 Red
	aa bb Cc		*aa bb Cc*
Gametes	*abC*		*abC*
	abc		*abc*

F_2 Zygotes	1 *aa bb CC*	Red 3
	2 *aa bb Cc*	
	1 *aa bb cc*	White 1

In similar fashion a 15:1 ratio in F_2 may be explained as follows:

Plants crossed	Red	×	White
	aa BB CC		*aa bb cc*
Gametes	*aBC*		*abc*

F_1 zygotes all *aa Bb Cc* Red

Plants crossed	F_1Red	×	F_1Red	F_2 zygotes	
	aa Bb Cc		*aa Bb Cc*	1 *aa BB CC*	Red—15
Gametes	*aBC*		*aBC*	2 *aa Bb CC*	
	aBc		*aBc*	2 *aa BB Cc*	
	abC		*abC*	4 *aa Bb Cc*	
	abc		*abc*	1 *aa BB cc*	
				2 *aa Bb cc*	
				1 *aa bb CC*	
				2 *aa bb Cc*	
				1 *aa bb cc*	White 1

The 63:1 ratio is the result of two reds, heterozygous for A, B, and C, all three, crossed together as follows:

Plants crossed	Red	×	Red
	Aa Bb Cc		*Aa Bb Cc*
Gametes	*ABC*		*ABC*
	aBC		*aBC*
	AbC		*AbC*
	ABc		*ABc*
	abC		*abC*
	aBc		*aBc*
	Abc		*Abc*
	abc		*abc*

Zygotes: 63 Red as follows:

$$\left.\begin{array}{l}1\ AA\ BB\ CC\\2\ Aa\ BB\ CC\\2\ AA\ Bb\ CC\\2\ AA\ BB\ Cc\\4\ Aa\ Bb\ CC\\4\ Aa\ BB\ Cc\\4\ AA\ Bb\ Cc\\8\ Aa\ Bb\ Cc\\1\ AA\ BB\ cc\\2\ Aa\ BB\ cc\\2\ AA\ Bb\ cc\\4\ Aa\ Bb\ cc\\1\ AA\ bb\ CC\end{array}\right\}\text{Red}\qquad\left.\begin{array}{l}2\ Aa\ bb\ CC\\2\ AA\ bb\ Cc\\4\ Aa\ bb\ Cc\\1\ aa\ BB\ CC\\2\ aa\ Bb\ CC\\2\ aa\ BB\ Cc\\4\ aa\ Bb\ Cc\\1\ AA\ bb\ cc\\2\ Aa\ bb\ cc\\1\ aa\ BB\ cc\\2\ aa\ Bb\ cc\\1\ aa\ bb\ CC\\2\ aa\ bb\ Cc\end{array}\right\}\text{Red} = 63$$

$$1\ aa\ bb\ cc\quad\text{White}$$

No new or anti-mendelian principle is involved, but simply an extension and natural result of the independent recombination of hereditary units which lies at the base of his whole theory.

(*d*) **Characters Dependent upon the Simultaneous Presence of Two or More Factors.**—In mice there is a well-established color variety known as "chocolate" or brown. The coat is a rich chocolate-brown, and the eyes are also brown pigmented. The hair pigment consists of brown granules distributed more or less diffusely as shown in Fig. 57, *a*.

There is also a variety of mouse known as "blue" or dilute black. The coat color is similar to that of a maltese cat. The eyes contain black pigment and microscopic examination of the hair shows *less* dense pigment than occurs in the brown animals with a peculiarly grouped arrangement of pigment granules (Fig. 57, *b*).

When a brown mouse is crossed with a dilute-black mouse, the resulting young are heavily pigmented, dense black in color, and the hair shows the number and distribution of pigment granules which characterized the brown parent with the qualitatively deeper black pigment of the dilute black.

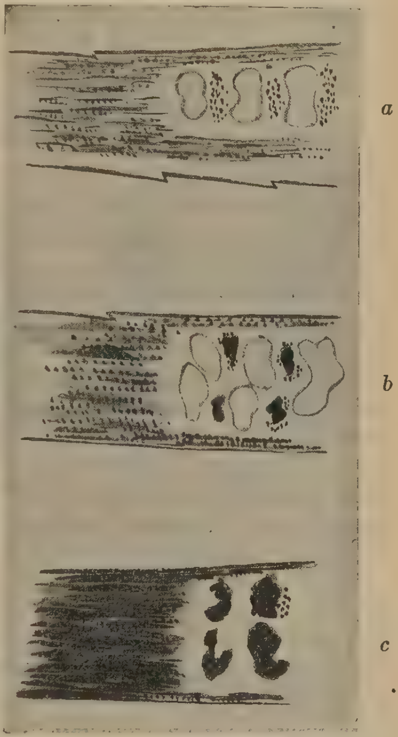

Fig. 57.—*a*, longitudinal section of hair of brown mouse showing pigment granules. (After Weincke, 1918); *b*, longitudinal section of hair of dilute black mouse. (After Weincke); *c*, longitudinal section of hair of black mouse. (After Weincke.)

When these blacks are bred *inter se* they produce four types of young in approximately the following ratio: nine black, three brown, three dilute black, and one dilute brown. The dilute brown has the grouped pigment distribution of the dilute black but the lighter pigment of the brown.

In this cross there are two pairs of mendelizing characters involved as follows:

B factor for black degree of pigmentation.

b factor for brown degree of pigmentation.

D distribution of pigment seen in brown and in black F_1 producing intense pigmentation.

d distribution of pigment granules seen in dilute black producing "dilute" pigmentation.

The cross made was

	Brown	×	Dilute black
	bb DD		*BB dd*
Gametes	*bD*		*Bd*
F_1 zygotes	All *Bb Dd*		Black

In this cross the character for intense black coat pigmentation depended upon the simultaneous presence of the factors B and *D*. Each parent race possessed one of these factors and the cross which resulted in bringing them together produced the new *black type*. Black coat color in mice is therefore a character dependent upon more than one factor or determinant. Many such characters in all sorts of animals and plants are known.

Modifying Factors.—In rats there exists a coat-color pattern known as "hooded." A diagram showing its ordinary appearance is shown in Fig. 58. It is recessive to solid colored or unspotted coat in inheritance. Experiments have shown that the hooded pattern differs from solid coat by a single determinant. The hooded pattern itself varies greatly and Castle believing that this variation indicated corresponding variation in the determinant underlying the hooded pattern, has carried on an extensive series of selections to form races with an increased and decreased amount of pigmentation. In this, he was highly successful.

The results were at first taken by him to mean that the determinant for hooded pattern had been quantitatively modified in the direction of his selections. From this he drew the conclusions at first that most, and finally that all mendelian factors or determinants were quantitatively modifiable by selection and that inconstancy was the rule among such factors rather than constancy.

By far the majority of workers in experimental genetics did not agree with this view but held that minor heritable fluctuations and variations in a character were the secondary effect upon that character, of the action during ontogeny of other genetic factors. It followed therefore, that these modifying factors could be possessed by, and inherited by animals, themselves not at all hooded. Such modifiers would tend to be approximately the same in any one family or race, as compared with distantly related or unrelated animals. If therefore, the plus and minus strains selected by Castle were crossed with a single solid colored race, and if the hooded animals obtained in F_2 were again crossed back and the process repeated for several times the two races should approach a common degree of hooding, all effects of selection being undone. This result has recently actually been obtained by Castle who crossed both plus and minus selection lines with wild rats and having obtained extracted hooded individuals repeated the process several times. The result was that after several generations the effects of selection were undone and the extracted hooded individuals from both plus and minus lines reached a common level. Castle, therefore, changed his conclusions as to the *cause* of the effectiveness of selection and adopted modifying factors as the probable agent involved.

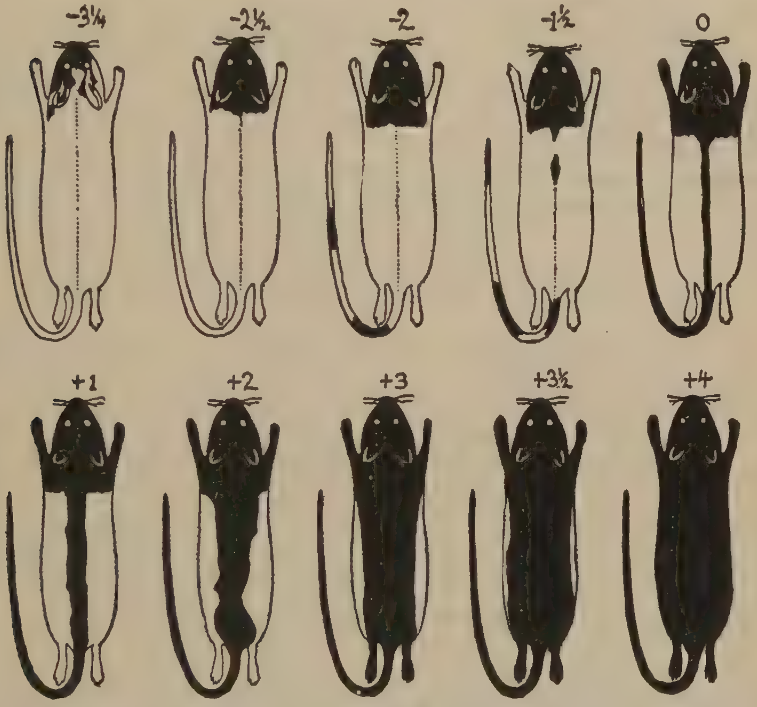

Fig. 58.—Diagram showing normal types of the hooded pattern in rats. This pattern is recessive in inheritance to solid-colored coat.

From the foregoing sections on Mendelism, it will be seen that investigators have been forced to the conclusion that the germ plasm contains a great number of chemical units or systems acting like units, which are the genetic factors and which act as the determinants of hereditary characters.

We have seen that some somatic characters have as their hereditary determinants one mendelizing factor and that others have several such factors, acting in a supplementary fashion, others are the product of the simultaneous action of two of more such factors. All apparently are subject to the effects of other genetic factors which cause minor variations and are known as modifying factors.

D. RECENT ADVANCES

1. The Physical Basis of Heredity.—The most notable advance of the last 8 or 10 years is in the increase of knowledge concerning the nature, localization, and spatial relations of these genetic factors or *genes* within the germ cell.

For brilliant researches in this line we are indebted to Morgan and his associates who have, at Columbia University, built up a coöperative school of experimental genetics of the greatest value. Working with the fruit fly *Drosophila melanogaster* they have discovered and have studied the genetic behavior of more than 230 pairs of mendelizing characters and have found that the factors underlying these characters fall into four groups, exactly the number of gametic chromosomes. Each group is entirely independent in inheritance of the other three. Within each group, however, the genes for the various characters are linked in various degrees and are *not* entirely independent of one another.

To explain this principle we should first refer to the diagram of the chromosomes of Drosophila given in Fig. 56. It will be noticed that the chromosome content of male and female individuals is not the same. It has been found by cytological investigation that when each sex forms gametes *one member of each chromosome pair goes to each gamete. The two members of each chromosome pair in the female are equal in size. They are equal in three of the four male pairs and unequal in the fourth pair* (indicated by arrow in diagram). The result of this is that the female forms one sort of gametes while the male forms two sorts. One of these receives the larger member of the unequal pair and is identical in chromatin content to the female gametes. When such a gamete meets a female gamete at fertilization, a female zygote results. The other male gamete receives the smaller member of the unequal pair and produces in combination with a female gamete a *male* zygote. This extremely important fact showing the inequality of the sexes in respect to chromatin content and the definitive role of the male germ cells in determining sex, has led to the pair of chromosomes which are equal in the female but unequal in the male, being designated as the "sex chromosomes" of Drosophila. Inequalities of chromatin influencing sex determination have been recognized in many forms. As the question of sex determination will be considered later in further detail, we may at this time, focus attention on the hereditary factors carried by the sex chromosomes. The first thing to be noticed is that the smaller element of the sex chromosome pair in the male, commonly called the *Y* chromosome, carries none of the genetic factors thus far recognized. The result of this is that the male cannot be homozygous for any of the factors carried in the sex chromosome. Factors carried in the larger element of the sex chromosomes of the male are therefore inherited as a unit, as the following cross will show.

If a wild female Drosophila, which has red eyes and gray body color is crossed with a *male* which has sable body color and vermillion eyes, all the F_1 animals are red eyed and gray bodied. This is because vermillion eyes depend upon a factor v which is recessive to V for red eye color and sable body color is dependent upon a factor s which is recessive to S, a factor for gray body color. Both factors are borne in the X chromosomes of the male and female as follows:

	Red-gray female	×	Vermillion-sable male	
	VSX VSX		vsX, Y	
Gametes	VSX		vsX and Y.	
F_1 zygotes	VSX, vsX		Red-gray female	(heterozygous)
	VSX, Y		Red-gray male	

The demonstration of linkage occurs when the F_1 animals are crossed back with vermillion-sable stock. The red-gray males give the simpler result and may be considered first.

	Red gray male	×	Vermillion-sable female
	VSX, Y		vsX vsX
Gametes	VSX and Y		vsX
Zygotes	VSX vsX		Red-gray female
	vsX Y		Vermillion-sable male

It will be noted that V and S entered the cross together from the red-gray male and v and s entered together in the gametes of the vermillion-sable female. *They came out together just as they went in,* neither of them having crossed over into the Y chromosome of the male. They are then completely linked in inheritance in this particular cross. The opposite cross however, gives different results as follows:

	Vermillion-sable male	×	Red-gray female (heterozygous)
	vsX Y		VSX vsX
Gametes	vsX		VSX
	Y		vsX
			VsX
			vSX

The female thus forms four kinds of gametes, but she does not form them in equal numbers. The original combinations VSX and vsX are about nine times as frequent as the new combinations vSX and VsX. This is shown by the ratio of the zygotes produced, as follows:

Zygotes formed	9 VSX vsX red-gray 9 vsX vsX vermillion-sable	females
	9 VSX Y red-gray 9 vsX Y vermillion-sable	males
	1 VsX vsX red-sable 1 vSX vsX vermillion-gray	females
	1 VsX Y red-sable 1 vSX Y vermillion-gray	males

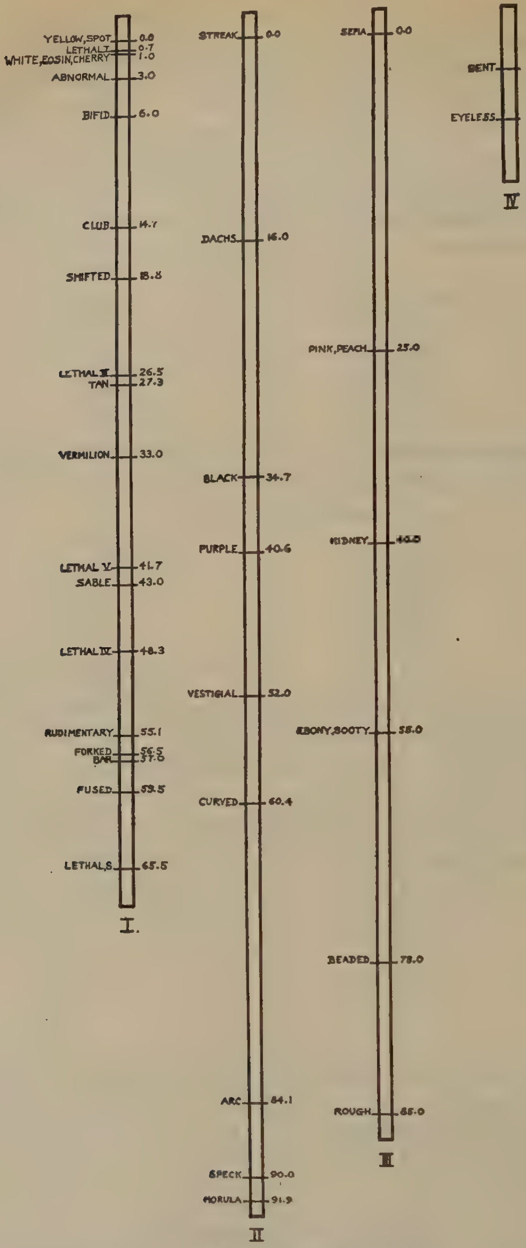

FIG. 59.—Chromosome map of Drosophila Melanogaster showing linear order of genetic factors or genes. The distances between genes are based on observed degrees of linkage in inheritance. Note that each of the four chromosomes shown as pairs in Column III, has its group of genes, and that while each group is independent of the other three, the genes within each group are linked in various degrees. (After data of Morgan, Sturtevant, Müller and Bridges.)

In about 10 per cent. of the gametes formed by the heterozygous red-gray female there has been a break in the linkage between the factors V and S and one of them has passed over into another gamete. In the remaining 90 per cent. however, they have remained linked in inheritance.

If the heterozygous red-gray female had arisen from the combination of Vs and a vS gamete instead of VS and vs, she would, in her gametogenesis, have given rise to nine Vs, and nine vS gametes to every one VS and one vs gametes. The principle then, is that there is crossing over between the Vv and Ss pairs only in about 10 per cent. of gametes formed. Other factors are contained in the sex chromosome as will be seen in Fig. 59. They are all linked with one another in proportion to the distance apart they are in the diagrammatic chromosome map. Thus the factors for yellow body and white eye show only 1 per cent. crossing over, being linked in inheritance 99 per cent. of the time. The distances between factors as shown by percentage of crossovers have been checked and verified with great care by Morgan and his associates. The accuracy of the values obtained is extraordinarily great and is striking evidence for the theory that the chromosomes are the bearers of the hereditary factors or genes.

2. Methods of Genetic Change.—We have seen that the *hereditary factors or genes* are peculiarly stable in most forms and that while there may be several different forms as in the solid colored, himalayan and albino rabbits, they are *not* in a state of fluctuation. We have also seen that De Vries' theory of mutation or sudden change seems to account satisfactorily for the appearance of most variations of an inheritable nature. No one has succeeded in producing mutations though several people have observed their origin in both plants and animals. Thus among the latter we have the origin of a great number of mendelizing characters in *Drosophila*, including some cases of reverse mutation from a recessive gene to its dominant allelomorph. In rats Castle and Phillips observed the origin of a mutation in degree of black spotting during their selection experiment. In mice I have observed the origin of two recessive and one dominant mutations, already described in other races of mice;—less well defined though probably authentic origins of mutations have been observed under experimentation in doves, canaries, cats, and dogs. Taken as a whole therefore, mutation is far from uncommon and the viewpoint of objectors to the mutation theory such as Jeffery and others is hard for one who has seen the origin of new forms in carefully controlled material to understand.

Two cases, one of a dominant, the other of a recessive mutation in mice may be taken as examples of typical conditions.

The ordinary wild house mouse has a brown, black, and yellow ticked upper coat and a gray ventral surface. The latter appearance is caused by dull lightly pigmented, gray-tipped hairs which, when the hair is turned apart are found to be dark, at the base. A variety of house mouse exists in which the tips of the ventral hairs are unpig-

TABLE 1.—TABULATION SHOWING THE OCCURRENCE OF WHITE-BELLIED AGOUTI MUTANTS IN TWO GENERATIONS OF GREY-BELLIED AGOUTI AND NONAGOUTI MICE

F₂ Generation

Mating	Black Agouti Gray-belly	Black Agouti White-belly	Black	Brown Agouti	Dilute Black Agouti	Brown	Dilute Black	Dilute Brown Agouti	Dilute Brown	?
A 32×13	4	—	—	2	1	2	—	1	—	1
B 14×17	2	—	—	—	1	—	1	2	—	2
C 8×20	8	—	6	3	3	1	1	—	1	6
D 16×18	4	—	—	4	1	—	1	—	—	—
E 33×22	2	—	—	—	—	—	—	—	—	5
F 21×20	15	1	2	4	3	3	3	2	1	—
G 9×31	10	—	4	8	4	—	3	2	1	—
H 7×31	3	—	4	1	2	—	1	—	—	—
I 6×18	16	—	3	3	3	2	3	4	—	—
J 23×17	9	—	3	3	2	—	—	—	—	—
K 30×19	24	—	6	4	5	1	2	2	2	—
L 15×13	15	—	3	3	4	1	—	—	—	—
M 12×22	12	1	4	2	3	1	2	1	—	—
Obtained numbers	124	2	35	37	32	11	17	14	5	14
Expected on three factor basis	116.1	—	38.7	38.7	38.7	12.9	12.9	12.9	4.3	—

F₃ Generation

F₂ Parents	F₂ Mating	Black Agouti Gray-belly	Black Agouti White-belly	Black	Brown Agouti	Dilute Black Agouti	Brown	Dilute Black	Dilute Brown Agouti	Dilute Brown	Pink-eyed Black Agouti	Pink-eyed Dilute Black
M	164×161	2	—	—	2	—	—	—	—	—	—	—
	163×161	3	—	3	—	—	1	—	—	—	—	—
	72×76	—	—	—	—	20	—	14	4	—	—	—
	163–164×161	14	—	1	11	—	2	—	—	—	—	—
L	331×335	—	—	—	2	—	—	—	—	—	—	—
	167×168	10	—	10	5	2	2	—	1	—	—	—
	165×168	2	—	1	—	—	—	1	—	—	—	—
	89×86	12	—	—	—	6	—	—	—	—	—	—
	84×86	16	—	—	—	9	—	—	—	—	—	—
	84–89×86	30	—	—	—	3	—	—	—	—	—	—
	165–167×168	7	—	5	2	2	1	—	1	—	—	—
K	280×320	1	—	1	—	—	—	—	—	—	—	—
	130×135	3	—	2	2	—	2	—	—	—	—	—
	57×56	3	—	2	7	1	—	—	1	2	—	—
	55×56	2	—	6	—	—	—	1	—	—	—	—
	51×56	4	—	6	2	—	2	—	—	—	—	—
	51–57×56	3	—	4	1	2	1	1	2	1	—	—
J	145×142	4	—	—	2	—	1	1	3	1	—	—
	144×142	3	1	1	—	—	—	—	1	—	—	—
	91×93	10	—	17	—	2	1	3	—	—	—	—
	90×93	—	—	35	—	—	8	6	—	5	—	—
	144–145×142	3	—	1	—	3	—	—	1	—	—	—
F	136×137	9	—	1	3	—	—	—	—	—	—	—
	136–140×137	6	—	1	2	—	1	—	—	—	—	—
G	185×182	—	—	—	42	—	10	—	2	—	—	—
H	110×106	3	—	5	—	3	3	5	2	—	—	—
	102–103×101–105	3	—	1	—	—	—	4	—	—	3	2
I	172–174×171	16	—	—	10	17	—	—	14	—	—	—
	80×78	4	—	1	—	—	—	—	—	—	—	—
	79×78	6	—	7	—	—	—	—	—	—	—	—
	79–80–82×78	16	—	20	—	—	—	4	—	—	—	—
	79–80×78	5	—	6	—	2	—	—	—	—	—	—
		200	1	137	93	72	35	40	32	9	3	2

mented and this surface is therefore, a clear white. This variety, known as white-bellied agouti, is dominant in crosses with the ordinary wild gray-bellied agouti house mouse. With yellow and with non-agouti (solid brown or black) the two agoutis form a series of quadruple allelomorphs. The origin of the white bellied agouti variety as a mutation under experimental conditions is shown in Table 1. It will be noticed that its occurrence is most infrequent and entirely irregular and unpredictable, and that it apparently originated in only a small proportion of the gametes of the mice which gave rise to it.

Quite different in its method of appearance is a recessive character. Here unless sex linkage is involved the actual manifestation of the recessive character will depend upon the meeting of two gametes both possessing the gene for the character in question. In the case diagrammed in Fig. 60 the factor for black pigmentation mutated to its recessive brown forming condition. The race in which it appeared was one of pure wild mice which was being closely inbred by brother to sister matings. Whether this fact has any significance in relation to the origin of the mutation is doubtful, though possible. The process of inbreeding, however, gave the best possible chance for two similar recessive bearing gametes to come together and thus for the recessive individual to appear.

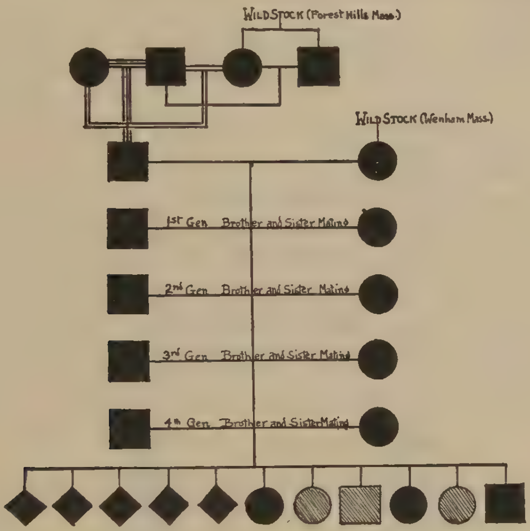
WILD STOCK (Forest Hills Mass.)
WILD STOCK (Wenham Mass.)
1st Gen Brother and Sister Mating
2nd Gen Brother and Sister Mating
3rd Gen Brother and Sister Mating
4th Gen Brother and Sister Mating

FIG. 60.—Chart showing origin of brown agouti mutants in mice. Solid symbols, wild-colored black agouti; line symbols, brown agouti mutants; circles, females; squares, males, diamonds, sex unrecorded.

It will be noticed that the recessives appeared in sufficient numbers to indicate that their parents were behaving as ordinary heterozygotes and were forming approximately equal numbers of gametes bearing the dominant, and gametes bearing the recessive member of the pair of allelomorphs.

We may conclude therefore, that mutation is an active process orderly enough to have assured the origin of precisely the same color types in various races entirely independently and in a clear cut though unpredictable manner.

3. Lethal Factors.—Another disturbance of the expected mendelian ratio is caused by so-called lethal factors or by the lethal action of mendelizing factors. What is apparently an example of the latter class is seen in the case of yellow coat color in mice. Yellow coat color in mice is dominant over and allelomorphic to the "black agouti" or gray coat of the ordinary wild house mouse. When two yellows carrying the black agouti pattern as a recessive are bred *inter se* we should expect that the progeny would consist of three yellows, and one black agouti as follows:

Let A^Y equal yellow, and A^G equal black agouti.
Yellow (heterozygous) A^YA^G × A^YA^G yellow (heterozygous)
Gametes A^Y A^Y
A^G A^G

$$\left.\begin{array}{l}\text{Zygotes } 1\ A^YA^Y \text{ Homozygous yellow}\\ \quad 2\ A^YA^G \text{ Heterozygous yellow}\end{array}\right\}\ 3 \text{ yellow}$$

1 A^GA^G Black agouti 1 black agouti

What one actually obtains is a ratio of two yellow to one black agouti, *and all the yellows are heterozygous.* No one has yet procured a homozygous yellow. Although thousands of yellow animals have been raised and hundreds tested they have all proven to be heterozygous.

The fact that the homozygous yellow class is missing and is *not replaced* by heterozygous yellows shows that the individuals forming it begin development but do not continue. The logical inference is that they die at some point between fertilization and parturition. Kirkham has recently shown histologically the presence of degenerating embryos in the uteri of yellow mice in the proportion expected if they were the homozygous yellow individuals. Disintegration begins apparently immediately after their implantation in the uterus and pro-

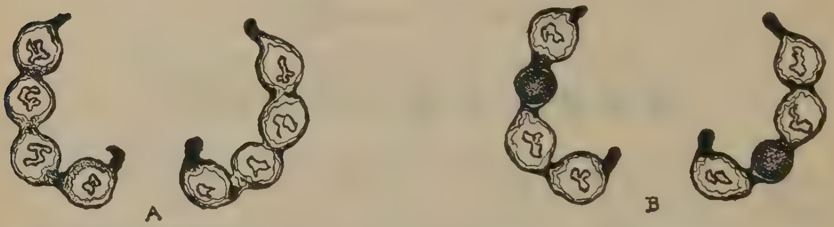

FIG. 61.—Idealized diagram of uteri of two female yellow mice each containing eight embryos, four in the right and four in the left horn: A, yellow female pregnant by non-yellow male carrying eight embryos destined to form yellows (heterozygous) and non-yellows in approximately a 1:1 ratio; B, Yellow female pregnant by yellow male carrying eight embryos destined to be approximately one non-yellow to two heterozygous yellows to one homozygous yellow. Experimental evidence has shown that the homozygous yellows always perish. The dark nodules are the sites of the degenerating homozygous yellows, surrounded by leukocytes.

gresses rapidly. This interesting histological verification of genetic evidence has been confirmed by more than one investigator. Figure 61 shows diagrammatically the occurrence of the degenerating homozygous yellow embryos.

There is also genetic evidence of at least two other such lethals in mice. One of these described by Lang produces a shortened and sometimes under developed and malformed tail. This condition is dominant to normal tail. The second is an extreme form of white spotting known as black-eyed white. In both these cases homozygous individuals fail to develop.

Many lethals occur in *Drosophila,* some borne in the sex chromosome and some not. The main principle therefore, of factors which eliminate the individuals possessing them either in all their gametes or, in the case of the male *Drosophila* in the X chromosome unbalanced by any normal allelomorph, has been clearly established and is of interest to all medical men as a possible explanation of the elimination of certain classes of human embryos at any time after fertilization.

4. Simultaneous Action of Many Factors.—An interesting masking of a form of mendelian inheritance is sometimes observed. This is true in cases where the character studied is one which depends upon the simultaneous presence of a number of independently inherited genes and upon their action when present in either a *heterozygous* or *homozygous* condition.

An example of this sort has been reported by Tyzzer and the writer in the reaction of mice to two transplantable tumors of the Japanese waltzing mouse, one a carcinoma (J.W.A.) one a sarcoma (J.W.B). The character studied is the support and growth of subcutaneous implants of the tumors.

TABLE 2.—COMBINED RESULTS OF EIGHT EXPERIMENTS WITH CARCINOMA J. W. A.

Class of mouse	Number inoculated*	Susceptibility	
		+	−
Japanese	58	58	0
Common	99	0	99
F_1	62	61	1
F_2	183	3	180
F^3	38	0	38
$(F_1 \times$ J. W.$)^1$ back cross	63	63	0
$(F_1 \times$ J. W.$)^2$ back cross	5	1	4
$(F_1 \times$ Com.$)^1$ back cross	78	0	78
$(F_1 \times$ Com.$)^2$ back cross	34	0	34
$(F_1 \times F_2)^1$	9	2	7
Total	629*		

* Sixty-three additional animals died too soon after inoculation to be included.

The carcinoma was the first worked on and gave clear-cut and striking results (Fig. 62). Upon implantation it grew in Japanese mice and failed to grow in common non-waltzing mice of two races. It grew in first generation hybrids between waltzing and common mice as well, if not better than in the pure waltzers (Table 2).

If now one attempted to follow the strict rules of dominance and to consider that susceptibility and non-susceptibility were due to a single pair of mendelizing factors, it would be expected that the F_2 hybrid generation, produced by breeding F_1 hybrid animals together, would show a ratio of about three susceptible to one non-susceptible animals. This however, is far from what actually happens for the actual numbers in the F_2 generation are three susceptible to 180 non-susceptible animals, a ratio of 1:60 instead of 3:1. When F_1 hybrids are crossed back with pure Japanese, all the mice inoculated have proved susceptible. When, however, F_1 animals are crossed to the common non-waltzing race, the 78 animals produced have all proved to be *non-susceptible*. These results are explicable on the supposition that the Japanese race possesses in a practically homogeneous condi-

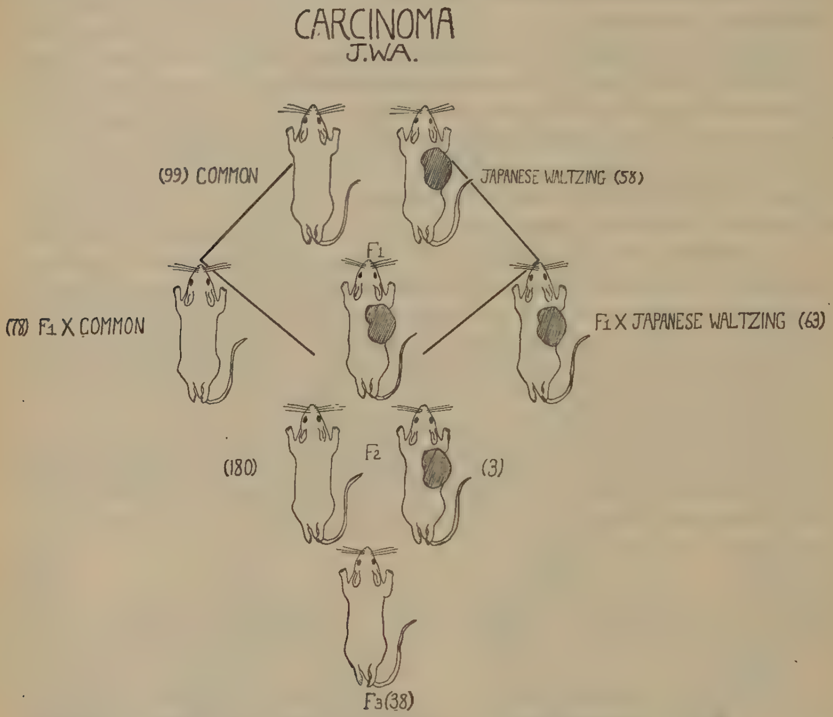

FIG. 62.—Diagram showing behavior of mouse carcinoma J. W. A. after inoculation in common mice, Japanese mice and their hybrids. The various generations are connected in descent. Shaded masses, mice showing growth after inoculation. If more animals of F2 had been raised it is extremely likely that susceptible animals would have been obtained.

tion a complex of mendelizing factors which the common non-waltzing race lacks, and which, when present, produces the type of physiological make-up which characterizes the Japanese race, and which tolerates and supports the growth of the Japanese mouse tumor. The next thing of importance is the fact that the presence of this factor complex in even a single dose is sufficient to give the Japanese-mouse type of physiology. The F_1 hybrids show this to be the case.

The chance of forming gametes and consequently zygotes which give by recombination the full quota of factors necessary for tumor growth decreases rapidly as the numbers of pairs of factors involved, increase. Thus the following table shows the calculated ratio of susceptible (+) to non-susceptible (−) animals in F_2 according to the number of factors which is supposed to characterize the Japanese waltzing mouse complex.

Number of factors	Plus	Minus
One pair	3.0	1.0
Two pairs	1.3	1.0
Three pairs	1.0	1.4
Four pairs	1.0	2.2
Five pairs	1.0	3.2
Eight pairs	1.0	10.0
Ten pairs	1.0	17.7
Twelve pairs	1.0	30.0
Thirteen pairs	1.0	41.0
Fourteen pairs	1.0	55.0
Fifteen pairs	1.0	73.8

The back cross generation between F_1 and Japanese waltzing mice is all susceptible for the Japanese mice again introduce all the necessary factors. The back cross with the common non-waltzing race is particularly interesting.

The chances of a susceptible animal being produced in this generation are directly dependent upon the proportion of gametes bearing the necessary complex which are produced by the F_1 animals. With various numbers of factors this ratio of plus to minus animals will vary as follows:

	Plus	Minus
One pair	1	1
Two pairs	1	3
Three pairs	1	7
Four pairs	1	15
Five pairs	1	31
Ten pairs	1	1,023
Twelve pairs	1	4,095
Fourteen pairs	1	16,383

From the F_2 ratio (Fig. 63) it will be noted that the observed ratio fits closely the expected ratio for 14 factors:

	Plus	Minus
F_2 Observed	3.0	180.0
Fourteen factors, expected	3.3	179.7

If this was the number of factors involved, the chance of a susceptible animal appearing in the back cross generation was as 1:16,383, and the actual odds in the 78 animals inoculated were negligible. Actually no such animal appeared, thus coinciding with expectation.

TABLE. 3—COMBINED RESULTS OF EXPERIMENTS WITH SARCOMA J. W. B.

Class of mouse	Number inoculated	Susceptibility	
		+	−
Japanese	200+	all	none
Common	450	3	447
F_1	20+	all	none
F_2	89	23	66
F_3	39	9	30
(F_1 × *Jw*)[1] back cross	25+	all	none
(F_1 × Com.) back cross	229	21	208
	1052+		

I have recently while working with tumor J. W. B. (FIG. 63), the sarcoma above described, obtained most interesting supporting evidence for the hypothesis of multiple factors underlying susceptibility as follows:

In the F_2 generation when tumor J. W. B. is used for inoculation, 23 susceptible and 68 non-susceptible animals have been obtained. This gives a ratio of 1:2.8. We have seen that if four factors are involved a ratio of 1:2.2 is expected, and if five factors, a ratio of 1:3.2. The observed ratio falls between these figures and leaves in doubt whether four or five factors are involved. In either event the case is simpler than that of the carcinoma J. W. A., and the back cross of F_1 × Common should give an interesting result and furnish a test of the ratio involved. Figures for this generation have recently been obtained in considerable numbers with the result that 21 animals have proved to be susceptible and 208 non-susceptible, a ratio of 1:9.9, much closer to the 1:15 expected in the four-factor case than to the 1:31 expected if five factors are involved. We may therefore, conclude that the difference between susceptible and non-susceptible animals in the races used probably depends upon from three to five pairs of mendelizing factors brought in to the cross by the Japanese race. On this theory it should eventually be possible to obtain races differing from the Japanese race by two, and by one factor, whose non-susceptibility depends upon these genetic differences.

This case then presents an interesting example of the dependence of such a complicated character as reaction to an implant of foreign tissue, upon a complex of mendelian factors whose presence and action would not become apparent unless, and until the test piece of tissue was introduced. The development of this phase of biology utilizing well-established races of known genetic make-up may lead to results of considerable importance.

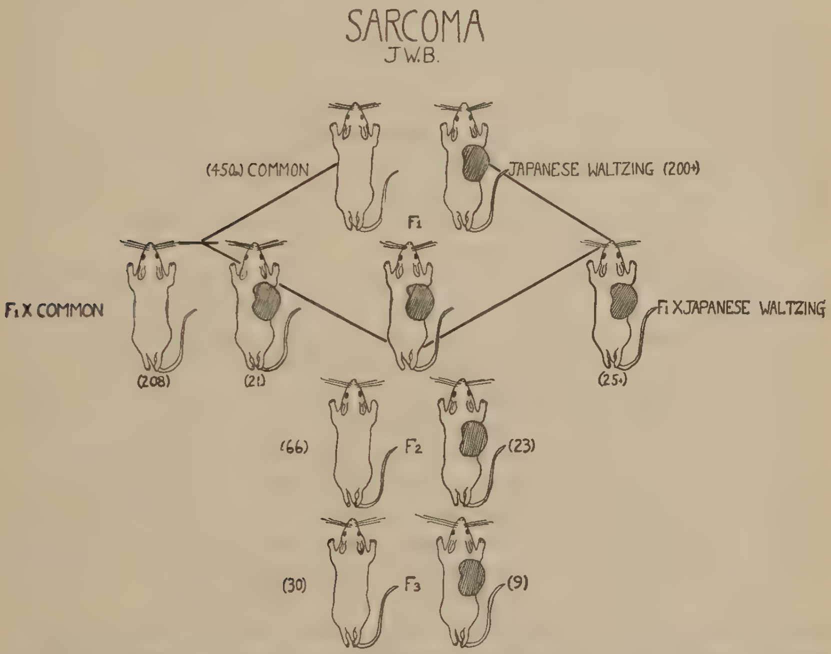

FIG. 63.—Diagram showing behavior of the mouse sarcoma J. W. B. after inoculation in common mice, Japanese mice and their hybrids. The various generations are connected in descent by lines and are described. Number of mice observed, in parentheses. Shaded masses show mice growing the tumor. In the common mice 3 out of 453 inoculated grew the tumor and are so recorded.

5. Pure Lines.—From the description of mendelian inheritance and the principle of non-inheritance of so-called acquired characters we can see that if a group of individuals all carried the same genetic factors and were homozygous in respect to the genetic factors which they all carried in common, they would, if crossed together, breed true and form a stable population devoid of variation unless such variation arose by mutation or by other genetic change occurring *de novo*. Such a similarly constituted true breeding group or population is known as a *pure line or genotype.*

The principle of pure lines was first emphasized and put to an experimental test by the Danish biologist Johannsen. He found that if beans of various sizes were self fertilized, the resulting populations had each a single center of variation, in respect to length, from which permanent progress by selection could not be made. Regression towards the mean length characterizing the race occurred when the largest or smallest beans in a given line were used as parents.

The work of Jennings with body length of Paramecium, the experiments over many years in selecting corn at the Illinois Agricultural Experiment Station, the work of Sturtevant and of MacDowell with quantitatively variable characters in *Drosophila*, and the experiments of Castle with the hooded pattern in black and white rats, have all shown that progress by selection consists in sorting out pure lines and that once an approximation to these lines is obtained, progress becomes impossible.

The *genes* which form the physical basis for hereditary characters do not commonly vary in minute amounts under the hand of selection. They remain strangely constant unless an actual mutation occurs. When we know more about the rate of mutation we shall be able to value more intelligently the practical role of selection in the evolution of either wild or domestic forms.

Recently Jennings and others have shown that biologically distinct lines may be isolated among the progeny of a single protozoan, reproducing by asexual processes. This interesting result does not alter our notion of the relative constancy of the gene. This is no evidence to show the close relationship of the protozoan to the germ cell, and there is in the myriad of forms, sizes, and functions among the cell-descendants of a fertilized vertebrate egg, a common proof of how diverse the descendants of a single cell may become. It is a question therefore of how far protozoan descent involving, as it does, the possibility of inequalities in distribution of both chromatin and cytoplasm during division bears upon the question of the modifiability of genes.

6. Sex Determination.—Ever since the existence of sexual differentiation as a wide spread phenomenon in nature has been recognized, scientific and medical men have been attempting in hundreds of ways to control the determination of sex. Few if any other phases of biological science have been so generally discussed, broadly investigated, and uniformly abused as has been this matter. The purely scientific interest in the problem has at times been overwhelmed and swept aside by the popular desire to control and to be able to predict sex of offspring for both agricultural and sociological reasons.

One outstanding fact has been obvious to all observers and investigators of mammalian, and in fact, of vertebrate material. This was the approximate numerical equality of male and female offspring in any large sample of births within a mixed population of the form under observation. This condition has therefore been recognized as the "normal" one. Departures from this in either direction of inequality, resulting in a marked excess of males or of females were eagerly noted and taken as promising starting points for further investigations. The tendency to return to an approximate equality of males and females, which continually manifested itself in these investigations was spoken of in general terms as the result of a "Law of Compensation" or some other mystic agent. This agent, sitting idly by while the disturbance in the sex ratio took place was supposed to exert its influence at the psychological moment to restore the proper order of things, wipe out the excess, and thus bring about a renewed wondering on the part of the investigators at the foresight of nature which saw to it that all of these things were properly done. A close relative of the "Law of Compensation" was that spasmodically active force, as yet unnamed which, dormant during times of peace, arose in its might when wars of considerable size occurred. At such times presumably keeping careful track of the number of males killed or disabled, it saw that society would suffer grievously were not more males than the ordinary number produced; and therefore it set about to produce the relative increase of males at the expense of the female sex and, by some entirely unknown method, is reported to have succeeded. Unfortunately, however, in view of the fact that no critical evidence has been produced for the actual existence of this particular force, it is placed in the somewhat precarious position of the many other less benign apparitions of fiction whose capture might provide excitement for sportsmen. but is not an immediate probability.

The first constructive line of work which tended to bring order out of chaos was that of McClung and his pupils, notably Miss Stevens. These investigators, all of them highly skillful cytologists, studied the processes of the formation and maturation of the sex cells in forms particularly responsive to microscopic technique.

As we have already seen, it is a characteristic of every individual produced by bi-sexual reproduction, that all the cells of its body have the same number of chromosomes. This is true of those cells within the gonad or germ tract which by a process of division and maturation elaborate the sex cells themselves.

McClung and his co-workers found that in certain forms, having, let us say nine chromosomes in the spermatogonia or second generation of cells before the sperm themselves, an equational division of chromatin occurred which resulted in the formation of spermatocytes of two sorts in approximately equal numbers having respectively five and four chromosomes. Thus, the so-called reduction division formed by the splitting of the chromosome pairs showed that one of the nine chromosomes was an odd, or a heterochromosome which in mitosis went *undivided* to one or the other pole of the spindle. By another division and subsequent metamorphosis those spermatocytes which had five chromosomes each, formed two sperm which contained five chromosomes apiece; similarly the four chromosome spermatocytes each formed two sperm with four chromosomes apiece. The result was that two types of sperm with unequal chromatin content were produced in equal numbers.

A further biological study of female individuals of the same species showed that their body cells each contained a total of ten chromosomes and that in the processes leading to maturation of the egg, the eggs themselves received five chromosomes, while the five mates of these chromosomes passed out with the polar bodies. It will be seen therefore, that while the sperm were dimorphic, the eggs were all of them, of one form. A five chromosome egg fertilized by a five chromosome sperm would produce a ten chromosome zygote. Similarly, an om fertilized by a four chromosome sperm would produce a nine chroeem some zygote, it was a natural conclusion that the 10 chromosoggzygote would be a female and that the nine chromosome zygote would be a male. These chromosome numbers had already been found to characterize male and female individuals of that species and in this way a logical and satisfactory explanation of the mechanism of sex determination was provided.

Since their first investigations, a mass of corroboratory evidence has been accummulating with the result that at the present time the case for dimorphism of either sperm or eggs differing in their chromatin content, as the *index* of sex determination, is clearly established.

We have already seen that in *Drosophila* the role of the *X* or sex chromosome in sex determination has been clearly shown by an analysis of genetic factors and by cytological methods. The phenomenon of non-disjunction discovered by Bridges in 1913, and investigated by him genetically and cytologically, serves to clinch the case in this particular material. Whether it is the relative size of the total chromatin mass, or an actual sex factor or factors located in the *X* chromosome that produces the difference between the male and female sexes in this form is, as yet uncertain. So it must remain until, by genetic evidence the conditions are so modified as to yield a satisfactory experimental test.

Recently Sturtevant has shown that, in *Drosophila*, female sex intergrades may result from the action of a modifying factor carried by a chromosome other than the sex chromosome. In these individuals the chromatin content as regards the *X* or sex chromosomes remains unaltered, but the presence of a recessive modifier changes the appearance of individuals from typical females to marked intergrades with certain male characters.

This work in the determination of sex should not be confused with the great number of attempts made to modify sex by changes in the external environment. All the last named experimentation may be classed together under the general term of experimentation in metabolism, as the cause of sex. The key to the great majority if not all, of the experimental work in this field which has yielded peculiar numerical deviations from the usual sex ratio may be found in a *selective mortality* during gametogenesis or the early embryonic stages of gametes determining, or of zygotes showing, one or the other sex as a result of variation in nutrition. In many forms the results are complicated by seasonal alteration of sexual and parthenogenetic forms. In certain other cases, chiefly among higher forms the criteria of sex and the measure of its modification under experimental conditions are based upon doubtfully valuable external characters. The danger of relying upon a close and accurate correspondence between an external and internal character especially those of the germ plasm should be most obvious. It still seems, however, to be one of the most general pitfalls for biologists.

7. Sex Ratios. **(a) General Considerations.**—Theoretically the sex ratio may be determined at any stage in the life of the individual. Since immediately upon fertilization an individual has its beginning in the formation of the zygote, it is obvious that this is the *first* point at which the sex ratio may be determined. In mammals, which in this connection are of primary interest to us, this stage is so difficult to discover and to observe that for the present at least the determination of sex ratios on the basis of chromatin conditions then prevailing is not likely to be made experimentally. In the smaller mammals capable of experimental breeding, it might be possible at early stages during pregnancy to obtain embryos which, upon microscopic section, would give data upon which to base an adequate conception of the sex ratio. Here again, the work would be tremendously laborious and the numbers necessary to insure accuracy so large, that data of this sort are not likely to be forthcoming. The earliest point at which the sex ratio is usually observed and recorded is at birth. To be sure, a certain amount of information on the sex ratio of still births and abortions has been obtained and will continue to be available. After birth the sex ratio may be, of course, obtained at any age desired. When this is done it will be seen that the effects of external environment such as war, disease prevalent in or limited to one sex, disease due to accidents contracted during employment and other such agents tend to distort and to modify the original conditions more and more as life progresses.

Various terms such as primary, secondary, and tertiary sex ratios have been suggested and are being employed in an attempt to designate the stage at which the data are collected, but this system is obviously, neither logical nor satisfactory, for if we conclude that, until more complete evidence exists, sex must be considered an attribute of the zygote and not of the gamete, then it follows that the first moment at which the sex ratio can be calculated is at fertilization, and this as we have seen is, in higher forms, practically impossible. All sex ratios therefore, that we can determine satisfactorily, must be "secondary," and to attempt by any general terminology to classify them according to their degree of "secondariness" will obviously be unsatisfactory. It seems then, that the only consistent method of designating sex ratios is to state as clearly and concisely as possible the stage in the life of the zygote at which the ratio in question is calculated. Thus, for example, we should have among humans, data on the human sex ratio in embryonic life (the months of pregnancy being designated), the sex ratio at birth, and at any later specified age desirable. Such a terminology is not capable of misunderstanding or of misuse. It

TABLE OF SEX RATIOS

	Ratio of ♂♂ to 100 ♀♀
Horse	98.31 (Düsing)
Cattle	107.3 (Wilchens)
Sheep	97.7 (Irwin)
Dog	99.2 (Little)
Pig	111.8 (Wilchens)
Rat	104.6 (King)
Fowl	94.94 (Pearl)
Dove	105.0 (Cuénot)
Mice	103.1 (Little)

further avoids indefinite terms referring to an order of sequence based on varying conceptions, and on individual systems of classification.

Four general causes appear to modify the sex ratio in a fundamental and measurable manner: they are (1) The "order of birth" within "pure" stocks, (2) Hybridization, (3) Lethal factors or substances and (4) Modifying factors. These may be briefly considered in order.

"ORDER OF BIRTH" RATIOS

	First births	Subsequent births	Differences
Stock Rats (King)	115.9±2.8	101.1±1.5	13.85±3.1
Inbred "A" rats (King)	129.0±1.3	114.9±1.2	14.1 ±1.86
Human (European inbred) Little	115.5±1.5	97.3±1.86	18.78±1.86
Human (European hybrid) Little	121.2±3.1	124.3±2.9	3.1 ±4.28
Human (U. S. white) Little	119.7±2.3	116.7±2.5	2.9 ±3.36
Human (U. S. colored) Little	93.6±2.4	97.7±2.0	4.1 ±3.17

(b) Order of Birth.—An inbred stock of laboratory rats at the Wistar Institute reported on by Miss King has a normal sex ratio of 104.6 ± .57. When the first litters which are included in this ratio are tabulated as a group it is found that the sex ratio was 115.9 ± 2.8 and in subsequent litters 101.1 ± 1.5 a decrease in proportion of males in subsequent births. Similarly an inbred line of rats selected for high proportion of males gave in first litters a ratio of 129.0 ± 1.3 and in subsequent litters a ratio of 114.9 ± 1.2, a qualitative result similar to the preceding. So also first births in European whites where both parents were of similar nationality gave a sex ratio of 115.5 and subsequent births a ratio of 97.3 ± 1.2. It is quite possible that the considerable correlation which exists between first births and the age of the mother has accounted for the apparent high male ratio in young mothers recorded by some investigators. On the other hand the high female ratio in young mothers which others have reported indicates, that the correlation is not absolute and that *order of birth* rather than age of mother is the chief point of interest.

Of scarcely less interest than the fact of the high male ratio in first births of *pure* races is the fact that no such difference is observable in hybrids. The three bottom lines of the preceding table bring this point out clearly. The greatest difference is only 1.3 times its probable error which is far removed from the "three times" which is considered necessary to establish significance.

(c) **Hybrids.**—Hybridization is one of the general physiological processes which very clearly and strikingly affects the sex ratio. In most forms it leads to an increase in the relative proportion of males. This fact taken in connection with the known genetic facts that the di-gametic sex in the diptera, and in mammals including man, is the male; and that in lepidoptera and in birds it is the female, shows that there are general factors which influence the proportion of the sexes and which act independently of whether the male or female is the di-gametic sex. For example: it has been found, as shown in the table below that in crosses between different races or strains of such forms as mice, rats, fowl, and man, there is a marked excess of male over female offspring produced.

TABLE SHOWING EFFECT OF HYBRIDITY ON SEX RATIO

"Pure" matings	"Hybrid" matings	Difference
Europeans, 106.27 ± .91	European F_1 121.56 ± 2.06	15.29 ± 2.26 = 6.76 × *P. E.* (Little)
Common mice, 103.1 ± 2.8	F_1 common × waltzing mouse, 118.2 ± 3.8	15.1 ± 4.72 = 3.2 × *P. E.* (Little)
Common rats, 104.6 ± 1.9	F_1, F_2, F_3, common × wild rats, 119.07 ± 3.57	14.4 ± 4.00 = 3.6 × *P. E.* (King)
Common fowl, 94.94 ± .57 (Pearl)............	F_1 hybrids between various breeds of fowl, 117.91 ± 4.7 (Davenport)	22.7 ± 4.73 = 4.8 × *P. E.*

It is interesting to note that the most obvious point which both categories have in common is the fact that the female forming gametes have actually more chromatin than the male forming gametes. Possibly on this fact a single explanation may be advanced to meet both cases. The differences between the pure and hybrid races are probably not nearly as large as they would be if more divergent forms are used, though they are because of this, none the less significant. Specific or generic crosses give an even more marked excess of males than the close varietal crosses given in the table.

(d) **Lethal Factors.**—In Drosophila sex-linked lethal factors have been found to have a marked affect on the sex ratio. These factors are carried in the *X* chromosome, just as any other sex-linked factors and are recessive in nature. The action of one of them is diagrammed in the table given below. The lethal factor, recessive and inactive in the female because of its normal allelomorph in the other X chromosome, is, by her, handed on to one-half her sons which are killed by it. This leaves the proportion of sexes in such a population one male to two females—a sex ratio of 50.0. Half the females will be free from the lethal and will give the normal equality sex ratio. The other half will continue to transmit the lethal and give the one male to two female ratio. The sex ratio of this generation, if a group of females are included, will, then be in the neighborhood of 75.0. It is easy to see how in a large sample from an heterogeneous population, the proportion of individuals carrying the lethal to those without it will vary from time to time. The chief indication which we may expect therefore, in the case of mammals, to show whether lethals are present in a population is an excess of *females* over what is expected for the population.

ACTION OF RECESSIVE SEX—LINKED LETHAL FACTOR

Let XX = ♀ n = lethal factor
XY = ♂ N = its "normal" allelomorph.
$NXnX$ crossed with NXY
Normal ♀ carrying lethal Normal ♂

Gametes NX and nX NX and Y
Zygotes $NXNX$ = normal ♀
$NXnX$ = normal ♀ (carrying lethal)
$NX\ Y$ = normal ♂
$nX\ Y$ = lethal ♂ dies!

Two good examples of inbred strains of mammals in which the sex ratio is suggestive of lethal factor action are the "line B" of rats (King) and a strain of Japanese Waltzing mice and hybrids which I have had under observation. The sex ratio in the former is 85.9 ± 1.39, and in the latter 78.7 ± 2.9. The former differs from the "normal" ratio of the type by 8.1 times its probable error, and the latter by 6.0 times its probable error. With the possibility of such fundamental disturbances in the sex ratio due to lethal factors it is wise to be remarkably cautious about treating the sex ratio as a unit as it has been considered frequently in the past.

(e) **Modification of the Sex Ratio by Alcohol.**—In the series of experiments already referred to, Stockard and Papanicolau have given certain data concerning the sex ratio in normal and alcoholic lines of guinea pigs. These data are included in Table 6 of the 1918 paper. Using the figures there given, and adding to them the probable errors in the experiments quoted, the following tabulation may be made.

These matings may be grouped into matings with male ancestors treated, matings with female ancestors treated, and matings with

Nature of matings	♂♂	♀♀	Ratio of ♂♂ to 100 ♀♀
Normal line	120	106	113.20 ± 4.88
Only father alcoholic	59	58	101.72 ± 6.22
Only mother alcoholic	121	125	96.80 ± 4.23
Both parents alcoholic	103	85	121.17 ± 5.42
Only ♂ ancestors treated	107	98	109.18 ± 4.92
Only ♀ ancestors treated	77	89	86.51 ± 4.84
♂ and ♀ ancestors treated	99	81	123.58 ± 4.26

both male and female ancestors treated. Each of these may be contrasted with the normal untreated controls as follows:

Normal line 113.20 ± 4.88 compared with	♂♂	♀♀	Ratio	Difference	Diff. P.E. of Diff.	Remarks
Male ancestors treated	166	156	106.41±3.85	6.79	1.09	Not significant
Female ancestors treated	198	214	92.52±2.87	20.68	3.6	Significant
♂ and ♀ ancestors treated	202	166	121.68±3.88	8.48	1.3	Not significant

It will be seen that the group in which female ancestors only are treated has the only sex ratio which departs significantly from the normal controls.

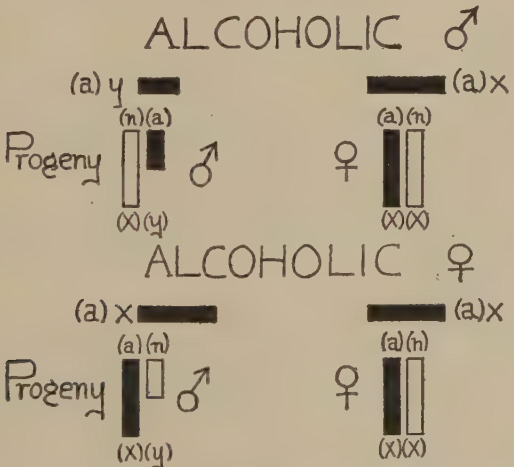

FIG. 64.—Diagram showing relation of chromatin possibly damaged by alcohol (black) to normal chromatin (outline) in both sexes. Chromosomes of the progeny of alcoholized guinea-pigs mated with untreated mates. (After Stockard and Papanicolau.)

There is produced by these matings a clear excess of female progeny. The question naturally arises as to whether an early differential mortality exists in these matings thus bringing about the deficiency of males.

TABLE 4.—SUMMARY OF DOCTOR KING'S SELECTION EXPERIMENTS, BROTHER TO SISTER MATINGS
Line *A* = High ♂ Selection Line *B* = High ♀ Selection

	Line *A*					Line *B*				
Generation groups	Number of litters	Number of individuals	♂♂	♀♀	Number of ♂♂ to 100 ♀♀	Number of litters	Number of individuals	♂♂	♀♀	Number of ♂♂ to 100 ♀♀
1–4	46	257	128	129	99.2	36	233	122	111	109.9
5–7	98	673	360	313	115.0	100	699	364	335	108.7
1–7	144	930	488	442	110.4	136	932	486	446	109.0
8–10	108	779	412	367	112.5	104	795	382	413	92.5
11–13	126	953	540	413	130.7	120	876	400	476	84.0
14–16	130	999	558	441	126.5	130	888	386	502	76.9
17–19	146	1144	628	516	121.7	138	1083	472	611	77.3
20–22	162	1270	698	572	122.0	152	1102	505	597	84.6
23–25	152	1129	624	505	123.5	150	1149	506	643	78.7
8–25	824	6274	3460	2814	122.3	794	5893	2651	3242	81.8
					±1.55					±1.56

Stockard and Papanicolau's data show that the progeny of alcoholized females have a significantly worse record in respect to early mortality than have those of alcoholized males. The percentage of early mortality in the former case is 51.08 per cent. ± 3.51 and in the latter is 33.33 per cent. ± 4.1. The difference which is 17.65 ± 5.39 per cent., is 3.2 times its probable error.

We have then, two striking facts that indicate an early mortality of male zygotes in the progeny of alcoholized mothers or of animals whose female ancestors were alcoholized. The probable explanation for this fact was indicated in a diagram given in the 1916 paper to show the *relative* amount of affected and unaffected chromatin in male and female progeny of alcoholized animals. Although in the 1916 paper, in which a diagram somewhat similar to the one here reproduced (Fig. 64) was given, the authors reached the conclusion that the *alcoholized male* transmitted more defects to his progeny than did the alcoholized female, their own diagram shows that both in *absolute* amount of abnormal chromatin and in proportions of abnormal to normal chromatin in the progeny, the *female* and *not the male* has the greater opportunity for influence. It is therefore, not surprising to find that in the 1918 paper the authors have recognized this fact, though no direct denial of the 1916 conclusions is made.

(f) **Modification of the Sex Ratio by Selection.**—If the sex ratio within a certain species is, let us say, 105.0 males to 100 females, and if the method of reproduction within that species is sexual (the sexes being separate) it is a matter of interest to determine whether or not selection would result in the isolation of races differing significantly in the sex ratio they possessed. If the species chosen represented at the start of the experiment a mixed population, it should be theoretically possible to isolate from it, races with very high male sex ratios on the one hand, and with very high female sex ratios on the other hand. This has been successfully accomplished by Doctor King of the Wistar Institute. The material used was a series of inbred strains of white rats. The results of selection are shown in the following table.

The theoretical aspect of the modification of the sex ratio by selection is extremely interesting. We have seen that sex appears to be correlated with a definite behavior of the chromosome mechanism and that this mechanism is calculated to produce, in the absence of disturbing secondary agents, an equal ratio of males to females, this ratio is, as it were, held in regulation by the accuracy of the distribution of the chromatin material. It has now been shown by King that by selection, certain races showing a marked departure from the equality ratio can be established and can continue to hold to these unusual ratios as one of their true racial characters.

It follows that either there has been established a large selective mortality resulting in a self-perpetuating excess of one or the other sex, or that the proportion of the sexes at fertilization is not wholly determined by the same agent that controls the chromatin characters above referred to. The fertility and size of litters of the rats in question favor the latter of these two hypotheses. It would appear therefore, that either mendelian or non-mendelian physiological factors which have a modifying influence on the proportion of the sexes must be considered as at least a probability. It should be pointed out in passing that there are several other pieces of investigation, a few of them stretching over several years, that have been advanced in support of this viewpoint. None of them, however, include results based on such a large number of animals of known pedigree continued for so many generations without outcrossing as do Miss King's They are therefore not cited since their results are not, in so far as known, contradictory to the general principle indicated by hers.

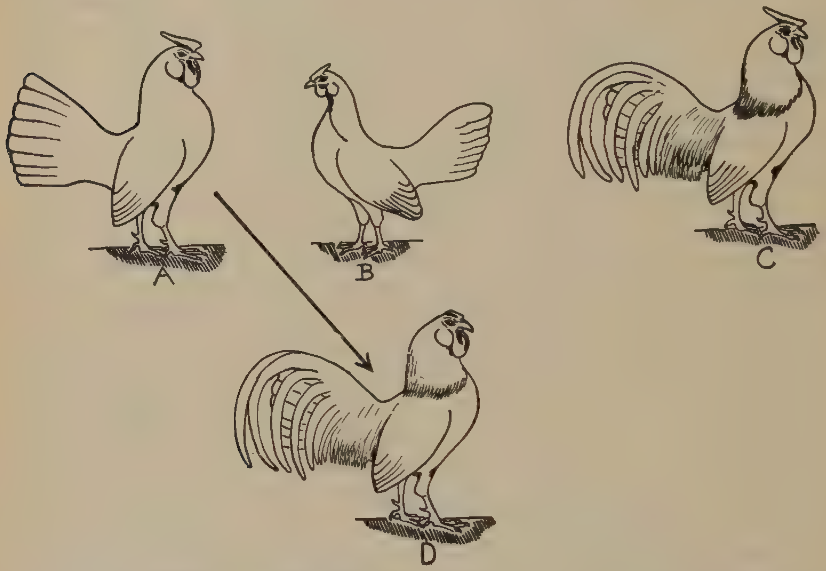

FIG. 65.—Diagram showing influence of gonads on secondary sex characters; A, male; B, female of "hen-feathered" breed of such fowl as Seabright Bantams; C, male of "cock-feathered" breed of fowl such as game bantams or leghorns; D, appearance of male after complete castration. Note assumption of cock-feathered plumage but reduction of comb.

8. **Sex Limited Characters.**—The influence of the secretions of the gonads upon the development of both avian and mammalian secondary sexual characters has long been known. The general findings of experimentation have been that in mammals a castrated male tends to assume a morphological, physiological and psychological makeup characteristic of the juvenile form of his species. The same is true of the castrated female. The work of Steinach and others has shown that castrated males may be actually "feminized" by successful implantation of ovarian tissue and that the reverse is also true. Castrated females can be "masculinized" by the successful implantation of testicular tissue.

In birds, Goodale, Morgan and others have obtained most interesting results. The juvenile character of the castrated or "caponized" male is well known. *Castrated females* of a sexually dimorphic species such as the Mallard duck assume *full male plumage* upon castration. So also does the castrated female of the fowl which shows comb, spur, plumage, and sometimes behavior characters of the male.

One series of experiments by Morgan are of peculiar interest in this connection. Sebright bantams (Fig. 65) have the males (*A*) and the females (*B*) both "hen feathered," the tail coverts, saddle and hackle feathers being short. Other breeds of fowl such as the rose comb bantam (Fig. 65, *C*) have the males with long hackles, saddles, and tail feathers. When the male Sebright is castrated, it develops the full male feathering of the ordinary breeds such as the rose comb bantams (Fig. 65, *D*). This interesting paradox of removing the male gonad in order to produce a *more* male appearance has shown the presence of actual inhibitive substances located in the testicle of certain breeds of fowl.

Breeding tests involving a cross between "hen feathered" and "cock feathered" breeds have shown that "hen feathering" is dominant. The return of fully "cock feathered" males in the back cross generation shows that the inheritance is probably mendelian and simple—depending upon one or two pairs of factors.

The bearing of the case upon the general theory of sex limitation is interesting. Cock feathering is limited to the male sex and depends for its presence upon the absence of the inhibiting female internal secretions. Another type of internal secretion essentially female in its influence has in some breeds become localized in the testicle and has modified the development of the full male cock feathering, thus producing a "hen feathered" male bird. The distinction between *sex limited* characters of this kind and *sex-linked* characters should be continually kept in mind.

IV. HUMAN INHERITANCE

In introducing this section of the chapter, especial attention should be called to the great handicaps which have faced investigators. Small families, slow breeding, and late maturity, are biological factors which make it difficult to obtain records of large numbers of individuals. The personal equation looms large in the giving and in the collection of data. This must remain so in spite of the most honest and conscientious efforts on the part of both the informant and the investigator.

In spite of these facts, the work done has been most creditable in amount and in quality. Nowhere has better work been done, and nowhere is more research at present in progress than at the Eugenics Record Office, now a part of the Carnegie Institution of Washington, at Cold Spring Harbor, New York.

Through the kindness of Doctor Davenport, its director, I am permitted to use many of the pedigrees here given. Medical men who desire to give or receive information on matters relating to human inheritance can do no better than to establish connection at the earliest possible date with the staff of this institution.

A. Physical Traits

1. Non Sex-linked. Albinism.—When investigators were determining the method of inheritance of complete albinism in lower mammals and finding that it followed closely the mendelian laws, it was hoped that albinism in humans would behave in a similar fashion. The monograph on albinism by Pearson, Nettleship, and Usher, served to show that there was more than one genetic type of this character and that its inheritance was not as simple as that of a single mendelian recessive.

Wright in a careful review of the inheritance of albinism in man has concluded that there are probably several degrees of albinism, all recessive to complete pigmentation and themselves falling into a multiple allelomorph series. The case would have a close parallel in albinism in guinea pigs, recently analyzed by Wright, or in the three allelomorphs of the albino series in rabbits. He also believes that multiple and modifying factors may be involved, and sums up the results of his analysis as follows ". . . it is sufficient to note that albinism cannot always be a single unit. We may say that albinism in most families is due to recessive unit factors, but we must be cautious in identifying the albinism of different families with each other and with the albinism of lower animals."

Eye Color.—The common eye colors of humans—blue and brown—were at first considered as a simple pair of Mendelian allelomorphs. though from the outset certain exceptions to the ratios expected under this hypothesis have been observed.

Davenport (1911) has tabulated certain matings as regards eye color as follows:

Parents	Offspring	
	Blue	Pigmented
Blue × blue	229*	1
Pigmented *DR* × blue	654	712
Pigmented *DD* × blue	0	136
Pigmented *DR* × pigmented *DR*	121†	248
Pigmented *DD* × pigmented *DR*	0	294

Hurst believes that there is a single mendelian unit difference between pigmented and unpigmented eyes, and points out the danger of confusing pigmented with unpigmented eyes, when the degree of pigmentation is very slight.

*Davenport states that 866 cases were not included because unchecked.

†A number of these blues are undoubtedly destined to become pigmented in later life.

Wright, however, feels that the condition is not so simple as this and that certain cases known to him in which blue eyed (unpigmented) parents have produced brown-eyed (pigmented) children invalidate the single factor hypothesis. It seems likely that all are right in a large measure and that we shall find a single factor explanation suitable to the majority of cases with perhaps additional genetic complications in certain families.

White Spotting.—We are familiar with many genetic forms of white spotting in lower mammals. It is not surprising therefore, to find at least two clearly distinct forms in man. One of these is clearly dominant in both sexes while the other, which may possibly consist of two distinct forms, gives evidence in some pedigrees of being sex-limited, and in others dominant in both sexes.

Piebald Spotting.—The first type known as piebald spotting has been excellently figured and pedigreed in Pearson, Nettleship and Usher's monograph on albinism. Occurring in its most striking form in negro races, it produces an individual with a broad white stripe running through the face and forehead, over the head, and affecting the face and hair. In addition there are some large white spots on the sides and ventral surface.

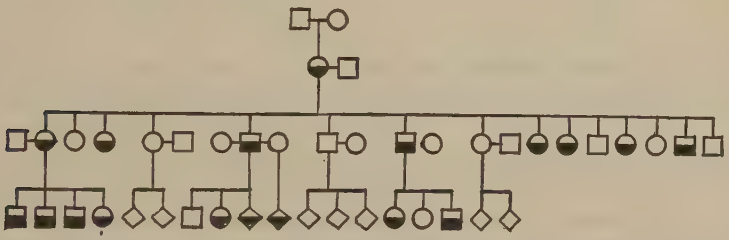

Fig. 66.—Pedigree of Piebald Spotting. (After Pearson, Nettleship and Usher.) Particolored symbols, piebald; outline, normal; squares, male; circles, female; diamonds, sex unrecorded. The behavior is that of a typical Mendelian dominant.

This character, behaves in inheritance like a mendelian dominant without any particular relation to sex. The pedigree given above taken from Pearson, Nettleship and Usher's monograph on albinism, includes data given by Simpson and Castle for a negro family in which the character occurs frequently, and in which its hereditary behavior can be clearly followed. Any attempt, however, to draw an exact homology between this factor and any of the dominant spotting factors in rodents, would seem premature.

White Blaze.—This character often described as a "congenital lock of white hair" is, as already stated, sometimes affected by sex, and sometimes apparently independent of it. A pedigree showing a family of the latter sort is given by Davenport from the data of Gossage after Rizzoli (Fig. 67). It will be seen that individuals showing the character are always the product of matings in which at least one parent has the character also. It behaves, therefore, as a dominant mendelian character.

In other families, such as the one after Holmes and Schofield, shown below (Fig. 73) it appears to be sex-limited and to be dominant in males and recessive in females. In this pedigree, it is noted that the character develops only at puberty. The case is therefore, comparable in many ways to the inheritance behavior of horns in sheep in which a given character may behave as a dominant in one sex, and as a recessive in the other in certain races, while in different races both sexes react in a similar fashion. The intimate relation between the secretions of the gonad and the appearance of the white spot in the family reported by Holmes and Schofield is seen in the fact that the white lock does not develop until puberty.

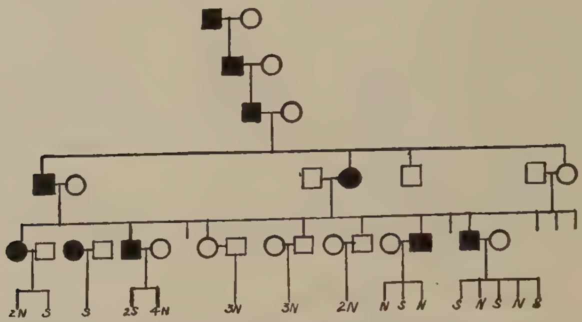

Fig. 67.—Pedigree showing inheritance of congenital lock of white hair. Affected, solid; S, spotted, sex unknown, both sexes affected. (Gossage after Rissoli.) The character behaves like a Mendelian dominant uninfluenced by sex.

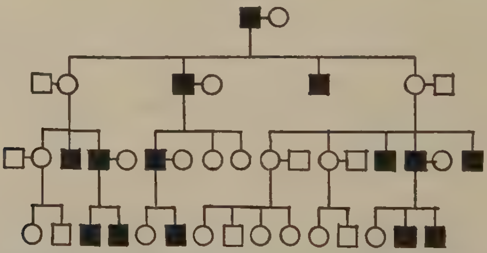

Fig. 68.—Pedigree of white forelock. (After Holmes and Schofield, 1917.) Appearing at puberty in males only and therefore probably sex-limited. Contrast with Figure 67.

The inheritance of this trait—so easy to observe and to record—is worthy of further study because of its theoretical interest.

Stature.—Since the time of Galton, human stature has been the object of investigation by students of genetics. It was first used as a standard example of a character which was continuous in variation and non-mendelian in inheritance. Work by Castle and his pupils on size inheritance in rabbits was similarly interpreted. Then in

1909–10, H. Nillsson Ehle and East independently showed that variations such as size, before considered continuous and non-mendelian, could as well be explained on the basis of many mendelizing factors with incompleteness of dominance. Another paper by MacDowell on size inheritance in rabbits took, as the most likely explanation, the multiple mendelizing factor hypothesis. A further series of size inheritance crosses in *Nicotiana* by East, gave additional evidence for the correctness of this hypothesis.

In 1917, Davenport published a most interesting paper on inheritance of stature in man. Utilizing a large amount of data, he reached important general conclusions, among them the following:

1. The offspring of two tall parents are less variable in stature than those of two short parents.
2. When both parents are "tall," or "very tall," and of tall stock, practically all the children are tall or very tall.
3. When both parents are "very short," or "short," and of short stock, all children are short or very short.
4. The hypothesis tested is that "short" parents may, and frequently do, carry germ-cells which lack the shortening factors, while in tall parents, the gametes are more nearly homogeneous and all lack most of the shortening factors.
5. The truth of this hypothesis seems to be established. Shortness is due to certain positive factors that inhibit growth of the various parts.
6. While "growth-as-a-whole" factors are present, yet there is a large degree of independence in the variability of the four segments of stature considered. Thus the correlations between suprasternal and substernal segments is 0.09 ± 0.04; between knee-to-pubic-arch and "knee-to-sole" 0.24 ± 0.04; between standing and sitting height 0.64 ± 0.03. Thus independence in variability of the segments of stature makes impossible any simple Mendelian inheritance of stature as a whole.
7. In the segments of stature (as contrasted with stature as a whole) we approach a condition of relatively few factors for the character.
8. There are families in our population characterized by idiosyncrasies in length of each of the segments of stature.
9. It is probable that in all forms of dwarfing there are multiple dominant inhibiting factors.
10. In the case of giants, when both parents are tall, all of the children are tall. This indicates that the factors for tallness are mostly recessive probably due to the absence of inhibitors to prolonged growth.

This approach to the subject has put the matter on a far firmer basis than formerly existed. The recognition of general and of more or less localized size factors is an important advance and should lead to even further discoveries in the future. A somewhat similar result has been obtained by Wright after a careful analysis of Castle's and

MacDowell's rabbit data. He found that besides general factors influencing size of the body as a whole, there was "a certain amount of variation of each bone independently of all others measured and there are also groups of bones which vary together independently of the rest of the body. Skull length and breadth on one hand, and the three leg bones on the other, are two such groups. Again the bones of the hind leg, femur, and tibia form a group subject to common influences which do not affect the humerus, a bone of the fore leg; and finally femur and humerus, homologous bones in hind and fore leg, vary together independently of the tibia."

Hair Color.—Two general facts have appeared from the study of the inheritance of human hair color. The first is that the various grades of hair pigmentation from extremely dark brown, or "black" to the lightest blond are arranged in a more or less continuous series of a very similar sort to that seen in the different grades of depth of color between full pigmentation and albinism in guinea pigs. The case in guinea pigs has been analyzed by Wright on the basis of a series of multiple allelomorphs, with a certain amount of incomplete dominance. It is very likely that a similar explanation with the possible assistance of modifying factors will eventually explain the observed facts in man.

The second general matter of interest is the behavior in inheritance of red hair. Several investigators, among them Cane, have given data on this trait. The figures in Cane's paper are especially interesting. For analysis the hair color is classified either as "red" or "non-red." The red character is apparently recessive. Red x red has given only a small number of offspring (11), but all are red, as expected. Heterozygous non-reds mated with reds have produced 46 red to 48 non-red; equality being expected. Heterozygous reds mated *inter se* have given 116 non-red to 59 red, the expected numbers on a 3:1 ratio being 132 non-red, to 44 red. It is possible that part of the excess of reds may be the result of the fact that matings which although $DR \times DR$ in constitution failed to give any RR (red) individuals would not be included because their true nature would not be recognized. Cane would not, however, claim too great definiteness for the case of red hair color and recognizes the complexities in the situation.

Hair Form.—There are three types of hair form commonly recognized—curly, wavy, and straight. Of these, straight hair is commonly recessive, and wavy is the heterozygous form between curly and straight. There is evidence that in some cases curly hair is completely dominant over straight hair, instead of producing heterozygotes with wavy hair.

Skin Color.—Davenport has published a large amount of data on human crosses between whites and blacks. The ordinarily intermediate appearance of the F_1 hybrid or "mulatto" generation, is of course, well known. By employing quantitative methods in determining the degree of pigmentation, Davenport has been able to show evidence of segregation. He has explained his results by an hypothesis which supposes that two mendelizing factors for pigmentation are present in the pure West African negro and that dominance is incomplete, giving an intermediate between white and black when either or both of these factors are present in a single dose. The matter needs continued investigation, for with such a slow breeding animal as man, proof of this, or indeed of any hypothesis, must rest on large numbers of progeny.

Hair Types.—There is, besides normal hair, a peculiar beaded form known as monolithrix which is dominant in heredity. Segregation is apparently clear cut.

Nail and Teeth Defects.—Defects of both teeth and nails are distinctly inherited, though sufficient data have not been collected to give opportunity for an accurate analysis of the type of inheritance involved. There is some evidence that defects of the nails are also correlated with defects of the hair, such as premature baldness.

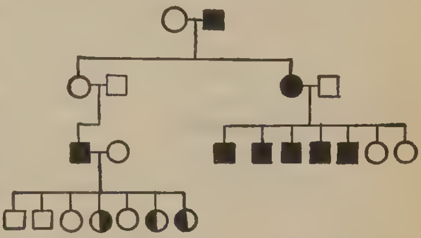

FIG. 69.—Pedigree showing inheritance of harelip and cleft palate. Harelip, solid black; cleft palate, half black. (After Schmitz, 1904.)

Harelip and Cleft Palate.—These defects are beyond doubt hereditary—occurring not only in man, but in dogs where their appearance in many members of a given family or strain is striking. Sample pedigrees of their inheritance is shown in Figs. 69, 70.

In both these pedigrees, the trait might be taken as behaving as a mendelian dominant, but other cases are known where affected individuals have certainly arisen from normal parents. This, of course, at once eliminates the possibility of a simple single factor mendelian hypothesis. The case is worthy of considerable further investigation.

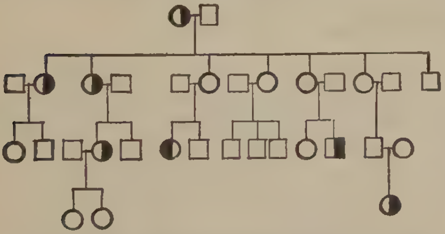

FIG. 70.—Showing pedigree of inheritance of harelip and cleft palate; harelip, right half dark, cleft palate, left half dark. (From Apert, 1907, after Schmitz.)

Cancer.—The inheritance of a tendency to the formation of multiple nerve tumors, recognized as multiple neurofibromatosis or von Recklinghausen's disease has been studied by Preiser and Davenport (1918). A pedigree of a family showing elephantiasis due to consolidation of multiple tumors is given in Fig. 71. It will be noted that the hereditary factor behaves essentially as a dominant suggesting that this particular type of tumor may be formed as the result of a simple mendelizing factor with no complications due to sex limitation. The clear correlation between mammary tumors and the female sex makes certain that there are many hereditary factors to be considered when all types of cancer are included. The tendency to localization of tumors in particular strains is evidence in support of this fact.

The hereditary nature of many types of neoplasms in mice, indicated by the work of Haaland, Murray, and Tyzzer, has been clearly demonstrated by Slye. The occurrence of strains in which many of the individuals develop cancer of a *particular type* shows not only inheritance of a tendency to form neoplasms, but in addition, *specific sorts of neoplasms.* Slye's work, which has covered an enormous series of individuals has shown beyond a reasonable doubt that in addition to factors determining general upsets in the control of growth, there are undoubtedly multiple modifying factors producing localized or specific types. The case, then, becomes closely analogous to the factors for stature. There are size differences limited by sex, and there are types of tumor so limited. There are size factors in plants and possibly in some animals giving simple single factor mendelian results. Perhaps these exist for some forms of cancer. There are general size factors influencing the whole body, and there are undoubtedly general growth factors—modification of which may produce general neoplasmic tendencies. There are specific size factors affecting skull length and width only, and there are apparently, hereditary factors producing liver tumors or lung tumors in given strains. Slye has, to be sure, advanced a single mendelizing factor hypothesis to explain the occurrence of all cancer. This in the face of her own data is unsatisfactory and unsupported by certain pedigrees.

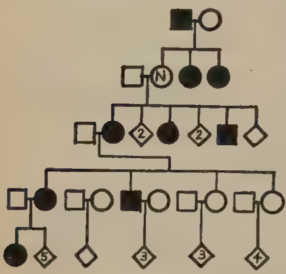

FIG. 71.—Pedigree of elephantiasis of left leg. (After Harbitz, 1909.) Extraordinary localization of confluent fibromata. With the exception of Individual N it behaves as a Mendelian dominant.

The fact that cancer is, relatively speaking, a disease of old age in mice as well as in men, makes the case further complicated. Unless, however, a given age is taken as an arbitrary limit, it will be entirely impossible to prove or disprove any type of inherited tendency to cancer. The adoption of an age limit should be possible, for Leo Loeb has shown that the age of tumor incidence varies markedly in different strains. This being the case, it is almost certain that selection for early tumor incidence would yield practical results, and allow the fixing of an age-limit—safely beyond the age of incidence—at and after which time the individual can be definitely classed as cancerous or non-cancerous, as the case might be. A single strain in which this had been carefully done would certainly give data more likely to yield analyzable *ratios* of cancerous to non-cancerous animals than a large amount of data collected under less controlled conditions. The facts of inheritance for mice undoubtedly give us a clue to the conditions in humans and we may safely accept the fact of inheritance of various tendencies to different types of neoplasms and await further investigations to give us clues as to the *nature of the process.*

Huntington's Chorea.—One of the clearest examples of a mendelizing character in man, and one of the first to be worked out, is Huntington's chorea. In inheritance, it behaves as a dominant over the normal type. This fact is clearly brought out by the sample pedigree taken from Davenport and reproduced in Fig. 72. Being a disease characteristic of adults, and being without marked symptoms during most if not all of the reproductive period, it is peculiarly vicious in its effect on the race. Its late appearance means that an individual is frequently already married and has a family at the onset of the disease. The offspring of this individual are then placed in a most difficult predicament. They have about an equal chance of developing chorea as adults, and if they do, their children in turn, should they have any, have the same cloud hanging over them. If, on the other hand, fearing the appearance of chorea, and the consequent handing of it on to their children, they refrain from marriage, they may find that upon reaching adult life, they do *not* develop the disease and that they have wasted their opportunity for happiness and the right to produce offspring. Until a method for observing symptoms during youth is discovered, those who will and those who will not develop the disease cannot be distinguished, and the decision as to the proper course to be followed must remain a matter of personal choice. It is, of course, clear that an individual with the disease should never marry. They are certain of handing on the disease to approximately half of their children and the proportion may often run higher as can be seen in Line IV of Fig. 72.

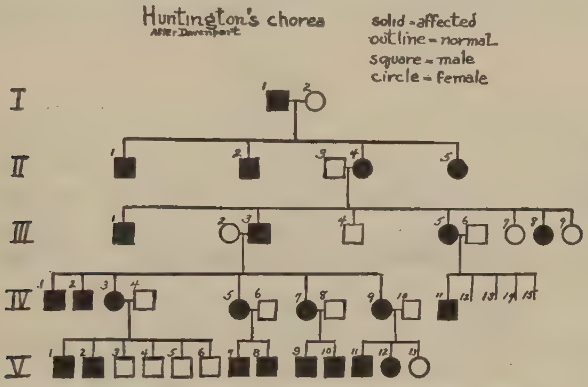

FIG. 72.—Pedigree of family with Huntington's Chorea. Behavior is that of a typical Mendelian dominant not influenced by sex.

Hereditary Ataxy (Friedrich's Disease).—This disease, usually beginning in childhood or youth, is also inherited as a mendelizing character. Like Huntington's chorea it is a dominant and a pedigree showing its inheritance would not in its essentials, be markedly different from that disease as is shown in Fig. 73.

Skeletal Abnormalities.—Hereditary fragility of bones, or osteopsathyrosis, is an interesting example of a trait which behaves as a mendelian dominant. Families in which it occurs show an amazing series of fractures following injuries which would have left a normal individual unscathed. Osteopsathyrosis is frequently correlated with blue sclerotics. Some individuals, however, with blue sclerotics, are of ample age to have shown any tendency to bone fragility which they might possess, but in this respect are seemingly normal. Other individuals are found who have marked bone fragility but normal sclerotics. Whether this indicates genetic linkage or modifying factors is not yet clear. It is, however, worthy of note in passing, that because of the dominance of both traits, breaks in linkage, did they occur, would become evident at once.

Achondroplasia, a rare structural abnormality resulting in a "dachshund"-like curving of the appendages is known to be probably dominant. The same sort of condition is dominant or partly so in sheep, cattle, and dogs. Exostoses, on the long bones, absence of clavicles, and certain defects of the hip are also known to be inherited, but have not yet been sufficiently studied to enable analysis of their exact hereditary behavior.

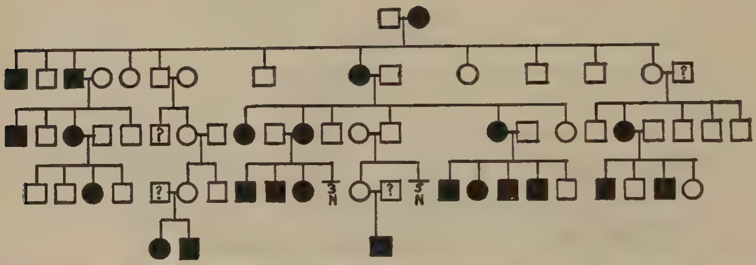

FIG. 73.—Hereditary Ataxy. (After Mott, 1905.) Solid symbols, affected individuals. No relation to sex.

Polydactylism, *Syndactylism*, and *Brachydactylism*, form an interesting group of very striking skeletal abnormalities clearly inherited. They are all of them ordinarily dominant. Occasionally, however, dominance may be incomplete or wanting, with the result that abnormal individuals may be produced by parents, both somatically normal, but one of whom at least is genetically abnormal, without showing the trait externally.

The close analogy between the behavior of these characters in man, and in the lower animals such as cats, guinea pigs, or poultry, is striking. In man however, the production of individuals homozygous for the dominant abnormalities is seldom, if ever, realized. We cannot therefore, be sure whether any of them are lethal in their behavior or indeed, whether the homozygous forms would show markedly different structural conditions from the known heterozygous types.

Diabetes Insipidus.—This disease is inherited apparently as a mendelian dominant. It is clear therefore, that persons affected should not marry since the probability is that at least half of their offspring will be similarly affected.

Diabetes Mellitus.—The fact of inheritance as regards this disease has been clearly established. It has, however, been less studied than diabetes insipidus and its exact behavior is less known. It is certain, however, that an affected individual may arise from normal parents, which suggests that it may be a mendelian recessive.

Two abnormalities of the urine, alkaptonuria and hematuria, are clearly inherited. The former is probably recessive, the latter dominant to the normal form.

Hypospadias or imperfect development of the male genitalia is clearly inherited. Because of its very nature, it is sex limited—occurring in males only. A pedigree showing its behavior is shown in Fig. 74. It follows closely the expectation of a mendelizing character, dominant in males and recessive in females. This is shown by the appearance of normal sons among the progeny of affected males, and of affected sons from normal mothers whose fathers in turn were hypospadiac.

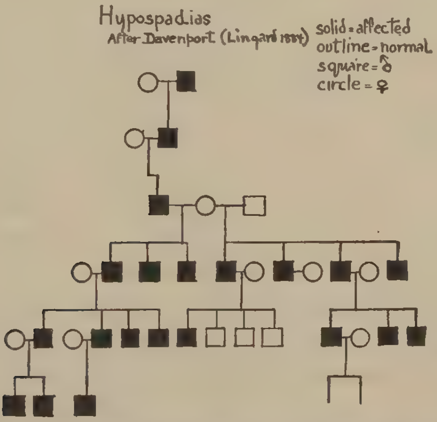

FIG. 74.—Pedigree showing inheritance of hypospadias; typical sex-limited behavior. The character manifests itself in males only. Each affected individual has an affected father.

Pellagra.—To obtain conclusive evidence concerning the rôle of inheritance in the transmission of pellagra is difficult. Davenport and Muncey have investigated family histories, and from work in the field have been able to demonstrate certain families which are characterized by mental symptoms. Others are characterized by intestinal symptoms, and still others by skin symptoms. There are evidently family "tendencies" towards one or the other form quite commonly. A tabulation of normal and pellagrous offspring according to their parentage shows that when both parents are normal, 41.8

per cent. of their offspring are pellagrous; when one parent is normal and the other pellagrous 15.9 per cent. of the offspring are pellagrous; when both parents are pellagrous 18.3 per cent. of the offspring are pellagrous.

The conclusions reached are that pellagra is not inherited in the relatively simple sense of brown eye color. The course of the disease however, depends on certain constitutional inheritable traits of the affected individual. Pellagra is probably communicable, but just how the communicable germ of the disease shall progress in the body depends in part upon constitutional factors.

The behavior of this trait has been entered into in considerable detail since it affords an excellent example of a complex character, as yet incompletely analyzed where similarity of symptoms in certain families indicate the presence of an hereditary factor but where the communicable nature of the disease complicates conditions to a marked degree.

NORMAL AND PELLAGROUS OFFSPRING ACCORDING TO THEIR PARENTAGE

Parents	Offspring		Per cent. pellagrous
	Normal	Pellagrous	
Normal × normal	280	133	41.8
Normal × pellagrous Pellagrous × normal	632	120	15.9
Pellagrous × pellagrous	98	22	18.3

Multiple Births.—The cause and frequency of multiple births in man has long been a matter of great interest to medical men and biologists alike. Davenport's recent studies of this matter have led to some interesting disclosures. The average percentage of twin labors in the population at large is about 1.1 per cent. In families where more than one pair of twins results, the parents may be classed as "repeaters." In such cases the families of "repeating" mothers show 4.5 per cent. twin labors, while families of "repeating" fathers show 4.2 per cent. If the fraternities of repeaters are further analyzed, interesting facts appear as follows:

Father's sister's children	8.2 per cent. twins.
Mother's sister's children	5.5 per cent. twins.
Father's brother's children	6.5 per cent. twins.
Mother's brother's children	4.5 per cent. twins.

These data include both multiparous and uniparous twins. If, however, cases of certain or highly probable identical twins only are tabulated, mothers and fathers both come from fraternities showing 13 per cent. twins.

Up to the present, there has been a general acceptance of the principle that there were as many young born as there were eggs liberated at any given ovulation. Davenport shows certain data obtained from swine in which 34 *corpora lutea* were accompanied by 22 embryos. The discrepancy may be due to: (1) Failure to fertilize all eggs, and (2) Failure of the fertilized egg to develop. In this connection the lethal factors already recorded in mice appear to offer supporting evidence. Davenport concludes that families producing twins do so because of multiple ovulations and also because sperm is active, abundant, and without lethal factors.

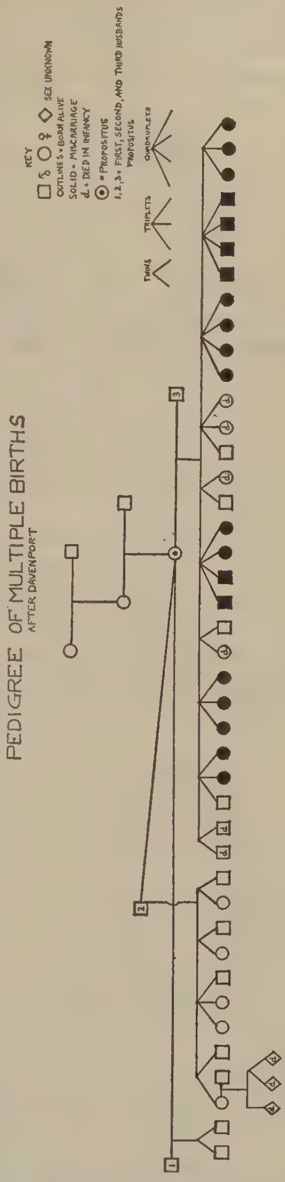

FIG. 75.—Remarkable pedigree of multiple births, giving a total of 41 children from a single mother.

Davenport has also given a most remarkable pedigree of a family showing a series of multiple births which is reproduced herewith (Fig. 75). The two female ancestors in the first and second generations are reported as being members of families in which the fraternities were entirely composed of multiple births. The propositas was married three times. *By each marriage, only multiple births resulted* totalling seven pairs of twins, five sets of triplets, and three sets of quadruplets, or 41 individuals. The only one of her daughters from whom children have been recorded, has had but one single birth and one pair of twins who died in infancy. Such a pedigree as this brings home forcibly the tremendous importance of the hereditary factors in multiple births.

Abnormalities of the Skin. *Epidermolysis bullosa.*—This trait shows, in a pedigree from Gossage after Bonajuti (Fig. 76) an hereditary behavior characteristic of a mendelian dominant affecting both sexes, approximately equally. In only two cases is it not known that the affected individuals are descended from parents at least one of which was affected.

Ichthyosis.—This trait behaves in a most interesting fashion as is shown in the two pedigrees. In the first case (Fig. 77) both sexes are affected, and the behavior is that of a recessive Mendelian character. In the other pedigree males only are affected, and the trait is apparently sex limited, being dominant in males and recessive in females. If such is the correct explanation, we should expect that the particular mating giving the large fraternity (Fig. 78) would produce one normal male, one male with ichthyosis, and two normal females. The numbers of each type obtained are actually five, four, and seven respectively—the expectation being four, four, and eight. The agreement considering the small number of individuals is remarkably close.

Tylosis.—This is also inherited but behaves as a normal dominant. There appear to be no irregularities nor any especial relation to sex.

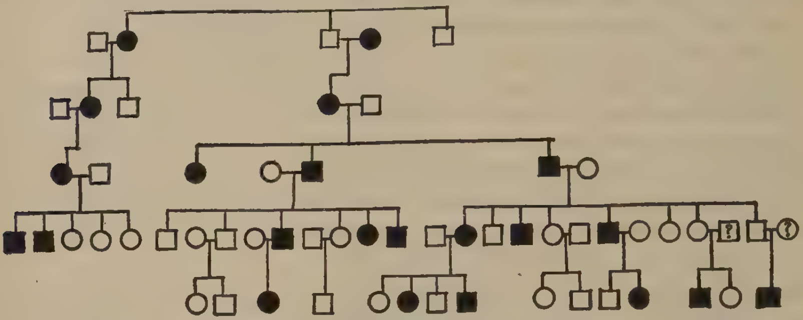

FIG. 76.—Pedigree of Epidermolysis bullosa from Davenport. (Gossage after Bonajuti.) Solid, affected; outline, normal; circle, female; square, male. Behavior is that of Mendelian dominant.

Eye Defects.—There are a number of eye defects which are clearly inherited. Some of them are sex-linked in their inheritance, and will be considered under that heading. There remain, however, several which are independent of or only slightly related to sex in their inheritance. These we may next consider.

Cataract.—This character ordinarily behaves like a Mendelian dominant, Loeb (1909) reports a total of 304 families and 1,012 children in which 589 or 58 per cent. showed the disease. This behavior is entirely in accord with the suggestion of its dominance.

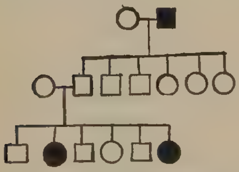

FIG. 77.—Pedigree of ichthyosis. (After Gossage, 1907.) Both sexes affected. Character apparently recessive.

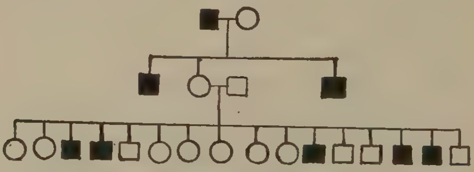

FIG. 78.—Pedigree of ichthyosis. (After Bond, 1905.) Males only affected. Inheritance either sex, linked or sex limited, probably the latter.

Ectopia lentis, *coloboma* and *micropthalmus*, or reduction in the size of the eyeball are all apparently distinct in inheritance and are all dominant over the normal type.

So also are two defects, *retinitis pigmentosa* and *hemeralopia*, or *night blindness*. The number of these characters which are dominant to the normal type is especially striking in view of the rarity with which dominant variations normally occur.

Ear Defects.—Generally speaking, ear defects are inherited. The method of inheritance is, however, in comparison with the eye defects listed, little understood. There seems to be no considerable evidence in favor of a small number of simple mendelizing characters. It seems rather as though multiple factors and modifiers were involved, and this would necessarily mean, slowness, caution, and some uncertainty during the completion of analysis.

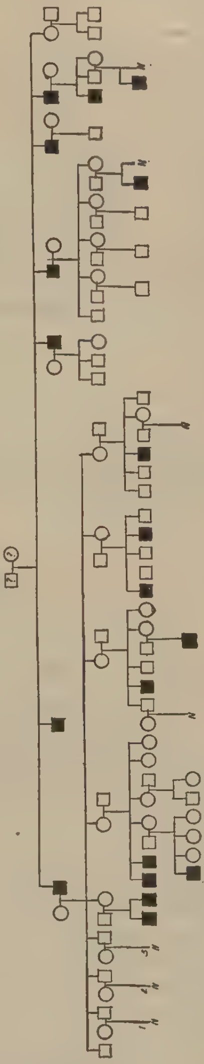

Fig. 79.—Pedigree of muscular atrophy. (After Herringham, 1888.) Recessive sex-linked character appearing in males only.

Right and Left Handedness.—Jordan (1911) has studied the hereditary tendency to left handedness and has given many pedigrees showing its behavior. The result of his work has led him to the conclusion that there is a distinct hereditary tendency to left handedness, but that the character manifests itself in many degrees of use of the left side of the body. No simple mendelian explanation will fit all cases. This is not hard to understand, for there must be many factors which contribute to the establishment of a series of associated activities which we have come to call left handedness or right handedness, as the case may be.

Hurst in a general paper on Mendelian inheritance in man, has considered the inheritance of left handedness. The ambidextrous are always a difficult class to deal with in such a study. Hurst has classified them as left handed in contra-distinction to Jordan who has classed them as right handed. If they are considered left handed, *DR* × *DR* matings have given 67 right to 21 left—suggesting the recessive nature of left handedness. If, however, left handedness is recessive it is clear that there are other factors involved which transform the ordinarily left-handed individual into an ambidextrous one or *vice versa*.

Manner of Clasping the Hands.—Every individual has a characteristic manner of clasping the hands with either the right or left thumb uppermost as the case may be. Lutz and Hurst have both studied the possibility of inheritance of this character. Hurst has concluded that its inheritance is not mendelian since about 50 per cent. of the progeny clasp their hands in each way. This trait needs considerable further investigation before its inheritance can be analyzed.

2. Sex Linked.—A considerable number of defects in man are to inherited according to the type of sex linkage seen in *Drosophila*. The defects are recessive and may therefore be carried by outwardly normal females, and by them be handed on to approximately half of their sons. The sons since they have only one *X* chromosome in which to carry sex-linked characters, are either normal or actually show the defects.

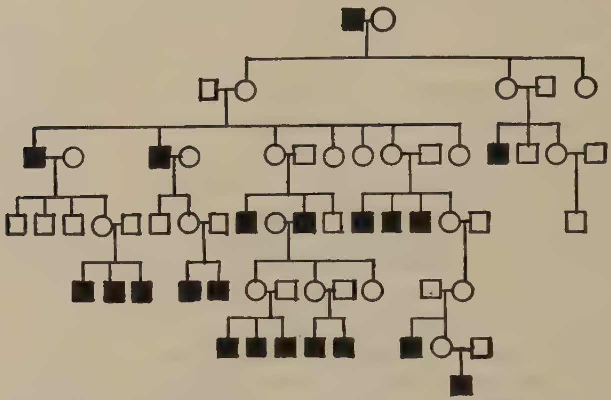

FIG. 80.—Pedigree of hemophilia. (After Bulloch and Fildes.) A sex-linked recessive character. Notice that males only are affected and that descent is through unaffected mothers, the daughters or granddaughters of affected males.

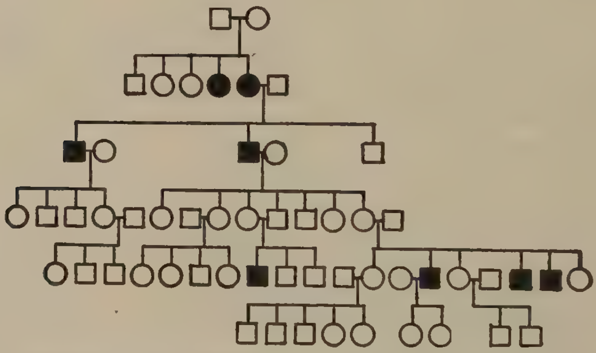

FIG. 81.—Pedigree of color-blindness, a sex-linked Mendelian recessive. (After Nettleship and Usher, 1915.) Affected mothers transmit the defect to their sons and these through their normal daughters to their grandsons.

The traits now identified as being in all probability sex-linked recessives are:

Muscular atrophy
Hemophilia
Atrophy of the optic nerve
Color blindness
Multiple sclerosis
Myopia (certain forms)
Nystagmus (certain forms).

A pedigree of a family showing muscular atrophy (Fig. 79) after Herringham (1888), will serve to demonstrate the method of inheritance. It will be noticed that males only, show the defect, and that they in most cases, are the sons of normal daughters, themselves children or grandchildren of affected males. Affected females can be produced if and when an affected male marries a normal female who carries the defect as a recessive.

It is likely that as other sex-linked characters are found, it may be possible to discover something of their linkage relations with each other. Conceivably there may be found linkage between some of the defects and some dominant, measurable, trait which would serve to designate which individuals were carrying the defect and which were not.

The similarity of behavior of sex-linked recessives may be seen clearly when the two pedigrees of hemophilia (Fig. 80) and of color blindness (Fig. 81) are compared with each other, and with that of muscular atrophy already referred to. The danger of confusing *sex-linked* recessives with *sex-limited* characters is very great, and should be continually guarded against in interpreting the data in human pedigrees. It will be seen that *in general, sex-linked* recessives are not transmitted directly from *father* to *son* while *sex-limited* characters commonly are. When experimentation is possible it can usually be shown that presence or absence of the sex-limited trait is correlated with presence or absence of the male gonads. On the other hand, castration has no effect upon the appearance of sex-linked recessives.

B. MENTAL TRAITS

Insanity.—In the case of insanity, we are of course faced with a tremendously complicated condition. There are many types of mental disorder, classifiable under this heading. Some are undoubtedly inherited but the exact types, surely heritable, and the method of their inheritance are as yet uncertain. Nevertheless, much good work has been done in compiling data on families inflicted with insanity, and the future will undoubtedly see even further progress. The principles of incompleteness of dominance, and modifying factors and the influences of sex limitation might well produce such a mixture of results as to lead to great difficulties before a satisfactory explanation or interpretation could be attained.

Epilepsy.—Here again there are many forms of the disease and presumably several causative agents. Types of epilepsy, however, have been found by Davenport and Weeks to be clearly hereditary. The general tendency is for the disease to behave as a recessive and there is some evidence of its close relationship with certain forms of feeble-mindedness.

Mental Ability.—The inheritance of the various types and grades of mental ability with the resulting opportunity to produce families, races or strains of exceptional or specialized talents, has a rightfully strong appeal to the imagination. Shining through the temporary shifts and variations of sociological conditions is the clear light of the biological principles foreshadowed by Darwin's work and made clearer by the investigations of Galton, Pearson, and the various eugenists of the mendelian school in the United States. The inheritance of general grades of mental capacity including feeble-mindedness and of specialized talent has been clearly demonstrated.

The facts now known concerning the inheritance of mental ability may profitably be considered under three main headings: (1) General mental ability, (2) Special traits and talents, and (3) Sub-normal mentality—Feeble-mindedness.

1. General Mental Ability.—Following the biometrical point of view which Galton initiated, Pearson and his co-workers have studied the degree of resemblance between sibs in respect to many physical and mental traits. This degree of resemblance they have expressed in the form of a fractional coefficient of correlation for the trait under consideration. They have found that in the cases of traits concerning the inheritance of which there can be no doubt, the coefficient of fraternal correlation is about 0.52. Following similar methods, they have measured resemblance within the fraternity in mental traits such as conscientiousness, temper, and vivacity, and have found the correlation to be about 0.50, or essentially equal. Pearson concludes that we are "literally forced to the general conclusion that the physical and psychical characters in man are inherited within broad lines in the same manner, and with approximate intensity."

It is clear that "general mental ability" is a term which upon even superficial analysis breaks up into elements of a more or less distinct nature. It is obvious that an exceptional mental aptitude for many, *i.e.*, for general purposes, may be formed by possessing either marked abilities of general value such as keenness, rapidity, and accuracy of perception, imagination, memory, combined with judgment, with balance, and with vigor; or from the possession of a number of highly developed special talents such as artistic ability, musical ability, judicial temperament, mechanical skill, and mathematical ability—representing such diverse lines of endeavor that the possessor becomes versatile beyond all ordinary limits.

Of course, the genius would combine the *general* and *special* abilities in various ways and in extreme degrees. Inasmuch as the mind for ordinary purposes must be a successful smoothly working system, it is not hard to see that excessive activity and capacity in some particular line might well lead to over-balancing the system and to mental disorder of some type.

Woods and Cattell have carried on a discussion as to the relative value of heredity and of environment in determining eminence in scientific work and in general mental capacity. To distinguish between the hereditary and environmental influences in large groups of individuals is always difficult, and often impossible. Having shown, as does Wood, that Massachusetts produces far more than her proportion of Americans with marked mental capacity, it remains an open question as to *what proportion* of this excess depends upon increased opportunity of environment and *what proportion* may be allotted to heredity. The point for us, to bear constantly in mind is that *both* influences are operative and efficient and that the greatest mental ability is not and never can be realized unless the optimum of inheritance is combined with the optimum of environment.

2. Special Traits and Talents.—Pearson's earlier work indicated that many special abilities of an hereditary nature existed, and the work of the more recent mendelians has done much towards their analysis.

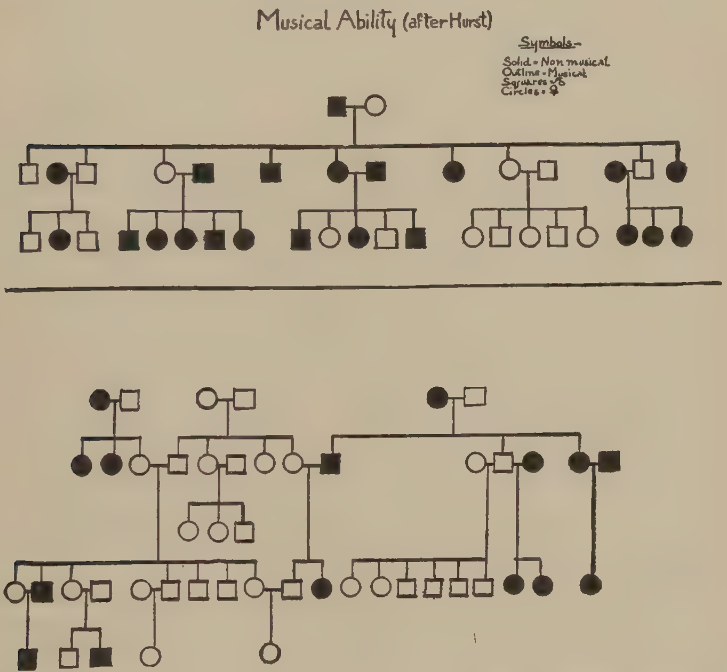

FIG. 82.—Two pedigrees of marked musical ability. (After Hurst.) Note that when two individuals with marked ability are mated only progeny with musical ability result.

Among the large number of traits studied, certain stand out as of peculiar interest and may profitably be taken as examples. These are (*a*) Musical ability, (*b*) Artistic ability, (*c*) Mathematical ability, and (*d*) Nomadic tendency.

(*a*) *Musical Ability.*—Davenport in 1911 stated of this trait, that when both parents are exceptionally gifted, all their children will be either of medium or exceptional ability. Thus from such matings, 81 exceptional, 120 fair and 1 poor individual resulted. The one "poor" individual is considered by Davenport as probably an error due to unsatisfactory returns or bad classification. When one parent is of high ability and the other low, the children will vary much; 257

offspring from such matings were lascsed as follows: *45 no ability, 128 intermediate, and 84 exceptional.* Davenport concludes that "the result indicates a partial blend in the musical ability of the offspring of mixed origin."

Later work by Hurst has indicated that in certain families at least the trait behaves strikingly like a Mendelian recessive. A pedigree of such a family is herewith reproduced (Fig. 82). It will be noted that two individuals without marked musical ability (solid symbols) may give rise to exceptional musicians among their progeny (outlined symbols), but that when two individuals of exceptional musical ability marry, all their children are exceptionally endowed.

Hurst's findings do not in any way preclude incompleteness of dominance and the effect of modifying factors both of which would tend to produce variation of the type noted by Davenport.

(*b*) *Artistic Ability.*—Havelock Ellis in his study of British men of genius pays particular attention to painters and sculptors. These he finds come from the lower and middle classes much more frequently than do most of the men of genius. "Of 63 painters and sculptors of definitely known ancestry only two can be placed in the aristocratic division. Of the remainder, seven are the sons of artists, and 22 the sons of craftsmen, leaving only 32 for all other occupations, which are, in many cases, trades that are very closely allied to crafts." Craftsmen constitute 9.2 per cent. of the fathers of eminent persons generally, and nearly 35 per cent. of the fathers of painters and sculptors. It is obvious that there is inheritance of special aptitude involved.

Davenport in considering this trait, finds a strong hereditary resemblance in families. He concludes that when both parents are exceptional, their children will in most cases, all have high artistic ability. When on the other hand both parents are from stock devoid of artistic talent and have none themselves, none of the children will show exceptional ability in art.

(*c*) *Mathematical Ability.*—As an example of inherited mathematical ability, Davenport cites the Bernoulli family, in which one individual, his two nephews and three sons of nephews were all mathematicians of high rank.

Allied to mathematical ability is calculating ability and the family records cited by Davenport give evidence on 728 offspring produced from parents both of whom are good calculators. Of these 92 per cent. were "good at calculating."

(*d*) *Nomadic Tendency.*—Nomadism or the wandering impulse, has been traced by Davenport through many generations, including large numbers of individuals. As a result of his studies, he reaches the following conclusions:

"The wandering instinct is a fundamental human instinct which is, however, typically inhibited in intelligent adults of civilized people."

"Nomadism is probably a sex-linked recessive mono-hybrid trait. It therefore follows that sons are nomadic only when their mothers belong to nomadic stock, and that daughters are nomadic only when their mother belongs to such stock, and their father is actually himself nomadic."

"When both parents are nomadic, expectation is that all the children will be."

"The nomadic impulse frequently occurs in families showing various kinds of periodic behavior such as depression, migraine, epilepsy, and hysteria. "He concluded that these periodic states are" not the true cause of nomadism, but rather that, for the better inhibited part of the community the nomadic tendency is released in the periodic state, which thus paralyzes the inhibitors. The feeble-minded and demented may wander without going into a periodic state. The periodic psychoses are frequent concomitants, but not the fundamental cause of nomadic impulses. They merely permit the nomadic impulses to appear."

Admitting as one may, the inherent difficulties in classifying and evaluating mental traits, it would seem that the above analysis of the nomadic tendency shows without doubt the fact of its inheritance, and goes far towards tracing the *nature* of its behavior in inheritance.

Many other mental traits have been studied, with the result that there is a steadily increasing mass of facts to show that mental traits will, when methods of classification are further perfected, fall into line with physical traits in inheritance. Undoubtedly the simple difference will be rare, but the mental trait or the instinct dependent upon a complex of mendelizing units will undoubtedly be the rule.

In considering these special traits it must at once become clear that the elements contributing to success in them need to be more completely isolated and analyzed before we can expect to reduce them to a factorial basis as definite as that attained in the case of such characters as piebald spotting or eye color.

Thus in calculating musical ability we have to consider as factors the structure of the vocal and respiratory organs, the accuracy of tone and pitch perception and production, the sense of rhythm, the imagination, memory, and in the case of instrumental music, manual dexterity.

Again, in artistic ability, skill in delineation, keenness of form perception and memory, and imagination are quite distinct. In mathematical ability, the rôle of memory and the proficiency in visualizing would be interesting to investigate more thoroughly. Similarly in valuing the nomadic tendency, the cause of unrest might be love of adventure, distaste of family, and home life, or from a desire to be alone. These motives are far from identical or from indicating similar traits in the individual.

We see therefore, that the fact of inheritance in all the cases is established, but that we must plan and carry out many further investigations before the matter can be placed on a satisfactory basis.

3. **Feeble-mindedness.**—The large amount of data on the inheritance of feeble-mindedness collected both by English and American eugenists is familiar to many medical men. Presenting as they do

one of the most clearly defined cases of a defect inherited as a mendelian recessive, the matter is worthy of the most careful consideration both because of its theoretical interest and its practical importance.

Goddard in his detailed and accurate studies of the inmates of the Vineland, N. J. Institution for the Feeble-minded has given numerous striking and enlightening pedigrees, one typical example of which is shown in Fig. 83. It will be noted at once, that (1) the offspring of two feeble-minded parents are feeble-minded, (2) normal individuals *may* carry feeble-mindedness as a recessive and when two individuals so carrying it marry, feeble-minded offspring may result, and (3) normal lines may be found apparently free from the trait, even as a recessive.

We have stated that feeble-mindedness is a recessive character, but this statement needs an important explanatory note. This is the fact that there appear to be several grades of feeble-mindedness and that these grades apparently arrange themselves in a series of multiple allelomorphs in inheritance. The series in order of dominance begins with normal mentality, and runs down the scale of increasing feeble-mindedness until the lowest grade is reached. It is a condition apparently roughly analogous to the series of multiple allelomorphs described in rabbits. Full pigmentation and full mentality are analogous, as is extreme feeble-mindedness and complete albinism. Between them we have a series of stepping stones replacing the single Himalayan type in the rabbits and consisting of various grades of feeble-mindedness.

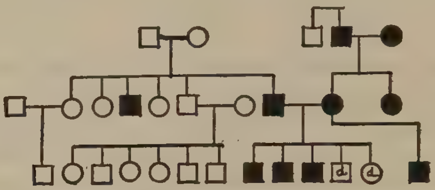

FIG. 83.—Pedigree of feeblemindedness. (After Goddard.) Behavior that of a Mendelian recessive. Solid, feebleminded; outline, normal; circle, female; square, male; d, died in infancy.

East has recently estimated the number of feeble-minded in the United States at 300,000—roughly 3 per 1,000 inhabitants. Of these, he concludes that 100,000 have been produced by matings of normal parents carrying the trait as a recessive. This means that there would be approximately 200,000 sibs of the feeble-minded, themselves carriers of the taint. Proceeding from this point, by careful reasoning he develops the tenet that probably more than 1 in every 14 individuals in the population carry as a recessive the hereditary tendency to serious mental deficiency.

To treat or remedy this condition, segregation of the deficients themselves is now practiced. Professor Punnett of Cambridge, England, in commenting on East's statements reveals the fact that by this method it will require about 22 generations before the proportion of carriers in the population is reduced to 1 in 1,000, and about 250 generations or 8,000 years before it is practically eliminated; *i.e.*, is found in about 1 in every 100,000 inhabitants. This being the case, it is obvious that new methods for detecting the carriers of the trait must be devised. On this point, both East and Punnett agree, and, taking advantage of the frequent incompleteness of dominance seen in other hereditary characters, suggest that the Binet-Simon or other proper tests would detect a lower mentality in carriers of feeble-mindedness than in pure normals.

The problem now confronting us is to build up broad lines of investigation by which the various elements comprising the complex known as "mental ability" or "mental capacity" can be gradually isolated, identified, and valued as agents of permanent value in improving the race.

The methods of bringing this about, are of course, many. The main lines of biological investigation, however, group themselves in a fairly satisfactory manner under five main heads as follows:

1. Experiments in infant and child psychology to recognize and classify types.
2. Establishment of a system of observation by which the ontogenetic psychological development of humans may be traced and recorded. This will result in obtaining valuable data on precocity and the attainment of early maturity—psychologically speaking.
3. Research in psychological methods to discern and separate the analyzable mental traits.
4. Investigation of psychological genetics in lower mammals, providing a sound comparative foundation for work with humans.
5. Continued collection of data on humans, many of whom will of course prove to be the ancestors of individuals concerning whom we have much better information and whose ancestry therefore becomes important.

C. CONCLUSION

The general conclusion that one reaches from a study of these cases of human inheritance is that there are many apparently simple mendelizing characters in man. Of these, not a few are sex linked in a way directly comparable to that seen in *Drosophila*. This indicates that in man the female is homozygous and the male heterozygous for the X or sex-chromosome.

Many other characters are apparently dependent upon more than a single pair of mendelizing allelomorphs. In some of these cases, it is not at all inconceivable that modifying factors may be discovered and analyzed.

In the great majority of characters, however, the fact of inheritance is plain, but the exact method of inheritance not so clear because of sex-limitation, incompleteness of dominance, or difficulty of diagnosis.

The practical point clear in all events, is that further research is essential. The possibilities of success, providing an efficient self perpetuating method of collecting accurate data is established, are great. Just what an important part medical men can and should play, in the collection of these data will be pointed out later, in the section on practical applications.

V. PRACTICAL APPLICATIONS

A. The Biological Nature of the Material

A factor to be reckoned with in all experimentation with living forms is the genetic nature of the material used. No set of experiments, whether we are dealing with bacteria, with laboratory mammals, or with man, can be properly planned or conducted without a most careful consideration of this matter. The biological nature of the material is a factor that cannot properly be overlooked. Until the relative rôles played by the various hereditary factors within the stocks or strains used are analyzed, the experimenter cannot be sure of the generality of the results which he obtains. Inasmuch as generality of application is one of the chief aims of experimental medicine as well as of biology, the factors which influence it should be continually borne in mind. The importance of such analysis has been becoming steadily more obvious during the advances in genetic methods and knowledge accomplished in the past decade. Not yet, however, have investigators given its consideration the weight that it deserves in planning or executing their experimental work. The result of this fact has been that much investigation which might have proven critical and conclusive has, at the last analysis, lacked the fundamental knowledge of the material involved without which it has proven inconclusive and of limited application. If, for example, we are studying the effects of alcohol on the mental capacity of rats, we must, as MacDowell has done, consider the influence of age, sex, and race, in order to understand whether there are strains genetically more resistant than others to the effects of alcohol inhalation. Without this knowledge of the reactions of various strains it would be impossible to say how far generalities concerning the effect of alcohol were justified on the basis of the actual experimentation performed. With this knowledge however, it becomes possible not only to obtain interesting information as to the genetic differences themselves, but also to obtain valuable indications as to whether or not the production of peculiarly resistant or peculiarly susceptible strains by selection, would be possible. The analysis of the genetic nature of any material can be accomplished in a more or less satisfactory way by the various types of experiments outlined in the first part of the chapter. All the available methods will undoubtedly leave something to be desired, before sufficient progress has been made to indicate definitely the relative importance of the individual genetic factors, and to develop a method of chemical analysis which yields sufficiently definite results to repay its adoption. To the investigator in experimental medicine then, as well as to the biologist, this matter of *genetic constitution* has become a prime necessity. A far more general adoption of this viewpoint will undoubtedly be attained in the near future and with this will come a more fundamental and general value to the experimenal investigation of the problems in both these fields.

B. CONSANGUINITY

The interest in matings of closely related individuals is of long standing in both the fields of biology and medicine. Involving as it does all the various degrees of inbreeding, it becomes a matter of practical importance to the medical investigator and the practicing pediatrician. The effects of close inbreeding on the physical and mental traits of the race has for so long been a matter of investigation and a grounds for diverse, and at times, contradictory conclusions, that a short consideration of the more important conclusions may prove valuable.

The existence of many various and successful types of plants in which self fertilization within the individual is the practice, shows that in so far as the essentials of normality of growth, form, and fertility, are concerned, outcrossing is unnecessary. Similarly, the long periods of vegetative reproduction observed by Woodruff, and by Erdmann in Paramecium, indicate that in lower animals the potentialities for normal growth and cell division can persist unimpaired for many generations without the introduction of outcrossing. In forms in which sexual reproduction is the rule, it has been shown mathematically that if brother and sister matings are made for several successive generations, the percentage of genetic uniformity technically known as homozygosity within the race, is increased rapidly. Such brother and sister matings represent the closest type of inbreeding possible in mammals, and are therefore, of especial interest to us. If a number of single pair matings of such mammals as mice are made, and are used as a starting point for a number of series of successive brother and sister matings, it will be found that some of the resulting races are weak and sickly, often dying out completely after a few generations. Other of the races show no marked difference from ordinary laboratory stocks, while still others are distinctly *superior* in size, vitality, and fertility, to the ordinary laboratory animals. The work of Doctor King at the Wistar Institute has demonstrated the establishment of such a superior race of inbred white rats following more than 20 successive generations of the closest brother to sister inbreeding.

It might be supposed that because of the various types of results obtained we were observing no controlled or orderly processes. Knowledge, however, of the increasing genetic uniformity of the inbred races gives us the key to the explanation of the obtained results. If the original pair of animals selected as the foundation of the inbred race, contain genetic potentialities either as recessive characters or as the result of combinations of factors which lead to weakening and inferiority in growth and vigor, inbreeding will result in perpetuating, and indeed in accentuating the appearance of such factors, as compared with the conditions found in the control laboratory animals. If the animals used as foundation stock have only a *small* number of such factors, balanced by a number of other factors producing normal or even superior growth, the inbred race will not be essentially different from the control laboratory animals. If, however, the original pair selected happen to have superior genetic potentialities, their descendants will inherit these and by inbreeding their appearance and effects will be increased and accentuated by a process of gradual sorting out. Inbreeding then, *per se* is not a creative constructive process, but is rather a *method of procedure* for producing hereditary uniformity. The *type* of race that will result from continued inbreeding, is determined by the nature of the genetic factors carried by the single pair of animals used as a starting point for the experiment.

C. The Value of the Practitioner to Science

If we admit, as seems certain, that the study of human genetics will be permanently continued, it is of interest to determine the most promising methods of advancing knowledge and of creating intelligent interest in this field. At present we find within it a peculiar mixture of interests, most of them with little if anything in common, and all of them collecting and interpreting data with no sincere attempt at coöperation. One of the many indications of separate action of this sort is found in the various points of approach to eugenics. The geneticist considers eugenics to be primarily *his* problem, but so also does the sociologist, the "sexologist," and the economist. The literal derivation of the word "eugenics" means "to be well born." If the claims of the four viewpoints given above are considered in this light, it is easy to see that each of them will afford its characteristic contributions to the subject. *Genetics* however, which deals *with the origin of inheritable variations, with the method and results of their inheritance, and with the variation and change of the inheritable factors involved, should have the dominant position in a proper valuation of the various approaches to eugenics.*

Sociologists may better the human race, and aid in being "well born" by improving the housing conditions, the community life, the sanitary conditions, and the financial opportunities offered. But their efforts are continually handicapped by the temporary nature of their results which demand a constant organized effort to insure their perpetuation.

Similarly a more complete and intelligent education concerning the matters of sex and of venereal disease must undoubtedly result in healthier children, fewer abortions and still births, lower infant mortality, and an adult population of increased efficiency. Control or practical elimination of venereal disease is essentially a permanent improvement in the race. As such it ranks on a par with progress resulting from truly genetic improvement. It thus parallels the relationship between the *transmission* of the syphilis organism and the *processes of true inheritance* which we have considered at some length.

Economists may bring about a more satisfactory and dependable food supply, and a minimum of social discontent, due to equality of economic opportunity, and, by these and other measures, a vastly better environment for the human race. All these things tend towards improved opportunities for being "well born," but economists like sociologists, must be ever watchful against unforeseen changes arising from unpredictable and uncontrolled complex relations between the minds of men.

Last of all then, we come to a consideration of the rôle which genetics must play. Investigators in this field, in spite of unsatisfactory and elementary methods of collecting, recording, and analyzing data, have made much progress. Though theoretically possible in the distant future, there is no advantage at present of considering the achievement of direct experimentation in human genetics. *Our chief opportunity for making more accurate and valuable the science of eugenics consists therefore, in improving methods of collecting, recording, and analyzing genetic data on human beings.*

The collection of genetic data based on hearsay evidence, or on the ordinarily indirect or verbally direct evidence of unskilled or prejudiced observers is of no permanent value. Any training of field workers consisting of instruction in the details of our present knowledge of the genetics of humans, previous to their starting on a problem, will never give such a great mass of unprejudiced, intelligent, trained observers as will be required to build up the necessarily enormous fund of current information concerning the genetic characters of man.

If one looks about for a group of men and women whose aims in life, ideals, and training would tend to fit them preëminently for this work, he must eventually turn to the ever growing, ever changing thousands of medical practitioners—not only of our country, but throughout the civilized world. These men and women are presumably capable of recognizing and classifying the abnormal, and in contrast, the normal types of human structure and function both physical and mental, as is no other group. Whatever their individual beliefs in the value of present-day genetics, they should agree willingly and actively to coöperate in every possible way by collecting and recording the bare facts of the form, structure, and physiology, of every human being with whom they came into professional contact. This is a vast task capable at best of slow achievement but of great and permanent value in providing a storehouse of information collected by competent and unprejudiced observers, from an immense number of human beings of all ages. The eventual value of this gradual and self-perpetuating method of collecting data will, after a score or two years, become incalculable. If, however, a contribution to biology and humanity forty or more years in the future does not appeal strongly enough to the present-day medical practitioner as sufficient reason for initiating a great coöperative movement in the collection of genetic data, he may possibly be convinced of its more *immediate* value by the realization that in this country, and all about us, the really critical generations of one of the most interesting and completed problems in human racial crossing that the world has ever known, are now being formed, and are capable of study, in the certainty of results of *immediate benefit and permanent value.*

For example, the sex ratios at birth, in matings involving various types of racial crossing, is a matter of great human interest, economic importance, and scientific value. The records of lying-in hospitals of ten or a dozen great cities could, alone, provide a fund of information on this point. By a few extra questions to incoming patients, concerning the ancestry of the child about to be born, and by a study of the records already commonly made, of the child at, and after birth, it would be possible to determine the relation of various types of racial crosses to matings within the race, in respect to the birth weight, birth length, rapidity and course of growth, early infant mortality, occurrence of multiple births, occurrence of structural abnormalities, head form, resistance to disease, and such problems. The relative value of matings between hybrid mothers and fathers of their own sort, between hybrid mothers and fathers of one or the other parent stock, between hybrid mothers and fathers of other hybrid stock, and between each of these categories, and matings within pure stocks can be studied in the case histories, as regards abnormality of position of the fetus, difficult labor, still births, toxemia, and other abnormalities of pregnancy or of parturition.

Similarly, study of the records of institutions for the mentally deficient and feeble-minded, might demonstrate characteristic racial differences and provide interesting comparisons in relation to hybrids. In both primary and secondary schools the attending physicians might well be able to obtain information of the greatest value concerning speed, accuracy, and specificity of the educability and memory manifestations of pupils of different racial ancestry. A serious beginning on the study of these problems must be made in the not distant future. Soon this country will find itself essentially a hybrid population, in which many of the biological elements of which we are now in almost complete ignorance, must be understood and reconciled. No greater contribution could be made to such an analysis than the utilization of the opportunity now open to medical practitioners. They, by coöperation, could build up a system of obtaining and recording data in a quantity and of a quality not possible of attainment by any other available trained or untrained group of observers. Certain medical men have long scoffed at, or considered of negligible value, the influence of inheritance. The ever growing public burden of the institutions for the feeble minded, the epileptic, the insane, the criminal—all of which types are strongly inheritable, is a direct challenge to such a viewpoint. Unless the medical profession can show a method of checking and diminishing this ever growing mass of socially defective individuals, they will soon be out of touch with, and left behind by those scientists and administrators who see clearly before them, in the already understood laws of heredity applied to these forms, an assured method of decreasing the numbers of deficients, from the moment at which society has reached a sufficiently sympathetic viewpoint to allow adequate action to be taken. The moment at which society will reach this viewpoint will be immeasurably hastened should the medical profession adopt with conviction and enthusiasm, the recommendations of biologists in these matters, and coöperate with them, in recommending the adoption of the proposed measures, and in educating a general public, with whom they are in the closest contact, concerning their value and practicability.

D. Heredity and Environment

A consideration of the phenomenon of heredity, no matter how brief, cannot properly be concluded without considering the inter-relation of heredity and environment. There are really two environments, —one of them internal, the other external. The internal environment is commonly overlooked because of its hidden nature. It is difficult to obtain more than a passing glimpse at the physiological processes which together make up the ordered life activities of the organism. Occasionally however, lines of experimentation are developed which unearth a store-house of information concerning some particular phase of physiological activity. In recent years, a study of the internal secretions has led to such a development. Experiments such as those with Sebright bantams, already described, or the transplantation work of Steinach and others, show that the hormones liberated by the active gonads are forces of the greatest importance in the internal environment. We can imagine the tissues in the various parts of the body at a period just before sexual maturity is attained, to be in the more or less stable equilibrium of a successful working system. At puberty with the awakened activity of the gonads, however, new substances are liberated into the blood stream, and are thus spread throughout the body.

The old balance is upset, and a new order established. Portions of the body, because of the responsiveness of the tissues located there to the stimulus of the new secretions, are thrown into a state of great activity and growth, while other portions of the system are left inactive. The internal environment has changed as fundamentally as does our external environment when spring becomes summer. To consider this internal environment as antagonistic to, or at variance with heredity is obviously a mistake. The whole visible manifestation of the hereditary characters is to be considered as a series of resting stages or end products of certain phases of the internal environment. The intimate relations between the genetic factors and the internal environment are further shown by the fact that the most promising avenue of approach to the germ cells in the hopes of inducing hereditary modifications, is through the medium and with the aid of the internal environment.

The relation between the *external* environment and inheritance is, however, not so clear, and is commonly the cause of the disagreements and antagonisms which are perpetually arising between biologists on the one hand, and sociologists on the other. Since it is in the human race that this difference reaches the maximum, it will be well to face the problem squarely on that field, and attempt to point out what must be true, namely, that the two points of view are not, and cannot be antagonistic unless they are colored with a dogmatism which succeeds in creating antagonism by its own force, and narrowness.

That improved environment would better living conditions and by this means affect fundamentally the individual throughout the course of his lifetime, is not questioned. There is, and always will be, room for humane and charitable effort toward bettering living conditions, until by the efforts themselves the cause for their existence is eliminated;—but it must be admitted that their success depends upon three great factors. These are, the stability of economic conditions, the consistency of sociological relationships, and the uniformity of biological material. A moment's consideration will serve to show that all three of these factors are and always will be, subject to change.

Economical conditions are always fluctuating, sociological relationships are liable at any time to be unexpectedly altered and upset, and the biological nature of the material, unless carefully controlled, will introduce unexpected and unpredicatable variables. If *any* such changes occur, new methods of procedure to insure proper environmental control will be necessary. The resulting complications are so enormous that the task is endless.

One generation of social workers can hand over to another an apparently improved civilization only to find that an unexpected overturning of sociological relationships occurs, which produces over night a series of problems more complicated and more difficult of solution than those already faced. The task is endless, and improvement through purely environmental agencies alone, can never attain permanent results. The fundamental strength of efforts to improve the environment lies in the immediacy of their results and in the consequent satisfaction of observing tangible improvements.

Such efforts are, as has already been stated, admirable. They do credit to their authors and to the participants in their accomplishment. They do not however, bring about permanent improvements, nor do they come as near to doing so as do other methods equally available.

If, as we have seen, characters acquired by the soma are not impressed upon the germ cells, we must admit two facts to be true. First, the inability of the external environment to produce a permanent influence on the hereditary constitution of the individual, and therefore of the face; and second, the basic and lasting influence of the hereditary materials carried by the germ cells, upon the race.

We know that the capacities for biological good or evil are present in varying degrees in different individuals. We know further, that these capacities are handed on from one generation to the next with a negligible amount of change. It is clear that if it were possible to wake up some fine morning and find that the race had, by some miracle, been freed from all traces of germ plasms that carried defects of mind or body, we should face the future of ourselves and of our children with a light heart. We should know that the *improvement was permanent*, and and that the race was clear once and for all of the drag of defective inheritance.

Of course we shall not have any such experience, but the thought of it does, nevertheless, bring out forcibly the soundness of the principle involved. Permanent racial improvement will come in so far as the germ plasm is improved—and no farther. By segregation or sterilization of defectives and criminals, and possibly later, by identifying and controlling those who carry as recessives, hereditary defects of certain sorts, we shall be making a start upon the right road. By investigating in infants, children, and adults, the psychological and physiological effects of racial crossing, we can do much to facilitate the adoption of intelligent policies towards immigration and the "Americanization" of our hybrid population. By educating our medical men in the methods of genetics, we can found and build up a great coöperative school of trained workers who can observe and record the variations and inheritance behavior of an enormous number of human beings.

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CHAPTER III

A SUMMARY OF THE ANATOMY OF THE INFANT AND CHILD

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INTRODUCTORY NOTE

The study of the anatomy of childhood is not a new one. The first work on this subject was written over 400 years ago and upwards of 300 theses, separate articles, and books were published prior to the nineteenth century. In recent years, the use of modern microscopical technique and the Roentgen-ray, and the introduction of the newer methods of statistical inquiry have greatly widened the field and enriched the literature. In 1913 alone there appeared over 300 articles dealing with the anatomy and physical development of the child; and a complete bibliography of the subject to date would probably contain between 5,000 and 6,000 titles.

The existence of this mass of literature should not lead one to the conclusion that the subject is now a closed one. On the contrary, probably no other branch of human morphology is so incompletely known. Most of the work has been done by students in widely separated fields—in human anatomy proper, pediatrics, anthropology, obstetrics, and legal medicine; and as there has been no central organ to correlate these investigations, we find frequent duplications of studies on the one hand and entire neglect of many phases of the subject on the other. These conditions make the production of even a moderately complete outline of the subject particularly difficult.

In order to cover the field as adequately as possible in a limited space the following general plan has been pursued.

The subject is presented from the systematic standpoint, but an effort has been made to cover the topography of the more important regions by means of a considerable number of illustrations which are cross-indexed under the various special headings.

Pre-natal development is considered only when necessary to make clear post-natal changes.

No details are given regarding structures which are practically the same in childhood and maturity since this information is easily available in better form elsewhere. Certain special subjects, such as the brain, the organs of special sense, the teeth, and the nasal sinuses, have necessarily received brief treatment; but references to more complete presentations are included in the text.

As many of the changes of the body during the period of post-natal development are best expressed numerically I have made frequent use of tables. These are generally based upon data collected from the literature, and on personal observations.

Finally, I have tried to point out some of the phases of the subject where our information is inadequate or our data conflicting.

An outline of this sort must be a mixture of the common knowledge of the subject, of personal observations, and of the conclusions of many other investigators. The last I have tried to acknowledge, in as far as space permitted, in the bibliography, but in common with all students of this field, I am particularly indebted to the works of Ballantyne, Symington and Gundobin.

THE SKELETON

General Remarks

As is well known the process of ossification begins in a number of discrete foci which are known as centers of ossification. These centers may appear either in membrane or in cartilage; in man by far the larger are formed in cartilage. The formation of ossification centers extends over a considerable period in the life of the individual. The first to appear (that of the shaft of the clavicle) is found in embryos of the sixth week while some associated with the vertebral column are not formed until near the end of the second decade of post-natal life. In all, something over 800 ossification centers are formed in the human body and of these slightly more than half appear after birth.

Almost all bones of the adult are formed from two or more centers of ossification; the relation of the total number of bones in the mature skeleton to the total number of centers being approximately as one is to four. The ossification centers of all bones of the body, with the exception of those of the carpus, tarsus, skull and sternum, may be divided into two general classes, the primary and the secondary. The primary centers, which form the greater part of the bone, almost always appear before birth. Such centers, when located in long bones are known as diaphyses. The secondary centers or epiphyses are, with one or two exceptions, formed during post-natal life. A further consideration of the nature of diaphyses and epiphyses will be found in the section dealing with development of the bones of the extremities.

As the formation of new centers and the fusion of older ones proceed at unequal rates during the first two decades, the number of separate bone-masses in the body varies from year to year during this period. Table 1 is a numerical summary showing some of these changes. As will be seen from this table the number of bones in the average full-term newborn child is 270. This number is somewhat reduced in the first two or three years of life through the fusion of primary centers which were present before birth. From this time until puberty, however, the number increases steadily through the formation of epiphyses and the ossification of the tarsus and carpus. In the fourteenth year there are about 350 separate bony masses in the body.

TABLE 1.—APPROXIMATE NUMBER OF OSSIFICATION CENTERS AND SEPARATE BONES IN THE HUMAN SKELETON AT DIFFERENT AGES

(Sesamoid bones omitted with the exception of the patellæ)

	Skull including auditory ossicles and hyoid bone	Vertebral column	Ribs and sternum	Upper extremity	Lower extremity	Total (paired bones counted as two)
Total number of centers formed................	Circa 120	Circa 295	Circa 101	Circa 140	Circa 140	Circa 806
Number of centers appearing after birth..........	9	Circa 197	73	82	88	Circa 443
Number of separate bones at birth................	45	93	34	48	50	270
Number of separate bones in fourteenth year.......	Circa 33	Circa 33	Circa 29	Circa 124	Circa 136	Circa 356
Number of separate bones at maturity............	29	26	25	64	62	206

After puberty the number of bones is again decreased rapidly until nearly the middle of the third decade and then much more slowly. Often it is not until late middle life that the number of bones is reduced to the quota of 206 generally accepted as the normal number in the human body excluding the smaller sesamoids.

There are great differences in the rates of bone formation in the different parts of the skeleton. In the skull, where the bones have no epiphyses, there is a steady reduction in the number of bones from birth to maturity. The spine shows a reduction in the number of bony elements during childhood due to the fusion of the primary centers of the vertebræ; but from puberty to 20 years there is a marked increase through the formation of epiphyses. Following the twentieth year the number again decreases, rapidly at first, through the fusion of epiphyses and primary centers and later more slowly as the segments of the sacrum and coccyx join one another. The number of separate bones in the thorax remains constant during childhood, is greatly increased by the formation of the epiphyses of the ribs after puberty, and is reduced after the twentieth year by the union of these epiphyses with their shafts and by the coalescence of the segments of the sternum. The number of separate bones of the skeleton of the extremities increases threefold between birth and puberty through the ossification of the tarsus and carpus and the formation of the epiphyses. After puberty, as the epiphyses unite with their respective shafts, the number of bones is reduced to practically that of the newborn appendicular skeleton plus the number of tarsal and carpal bones.

Together, the bony and cartilaginous skeleton form from 15 to 20 per cent. of the total body weight at birth. Its post-natal growth proceeds parri passu with that of the body as a whole and, so far as our rather meagre statistics show, the proportions between the skeleton and body-weight which exist at birth remain practically unchanged during childhood and maturity. The absolute post-natal increase in the weight of the skeleton, like that of the body as a whole, is roughly twenty-fold.

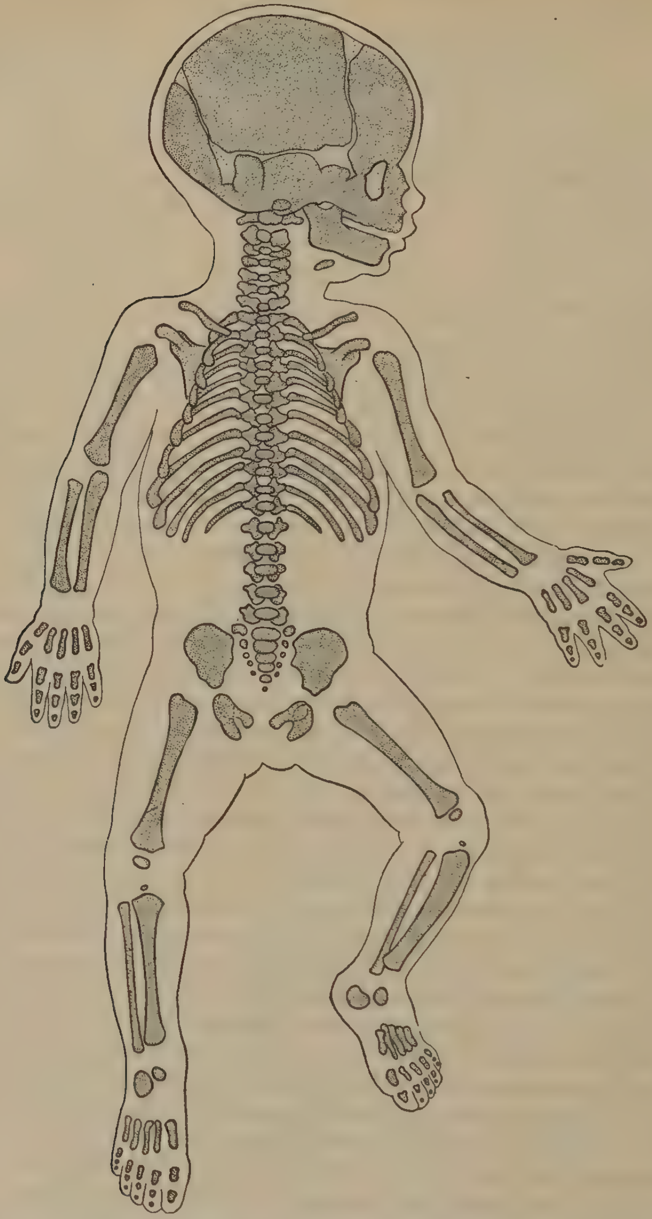

Fig. 84.—A semi-diagrammatic outline of the skeleton of the full-term newborn as seen with the roentgen-ray. The ossification centers of the sternum are omitted. (Slightly modified from Hess.[29])

FINER STRUCTURE OF THE BONES IN CHILDHOOD

As the histology of bone development is described in almost every modern anatomical text the present section is limited to a summary of the finer structure of fully formed osseous tissue in childhood.

The bones of the infant are much more spongy in structure than those of the adult. This sponginess or porosity has recently been studied quantitatively by Toppich [57] who found that nearly 60 per cent. of the bulk of the bony skeleton of the newborn was made up of material other than osseous tissue. With the exception of the vertebral column, all the divisions of the skeleton show a reduction in porosity during childhood. In the vertebral column the porosity increases from about 61 per cent. in the newborn to 75 per cent. in the mature skeleton.

The histologic picture presented by sections of the long bones of young infants is quite different from that seen in the adult. In the former the bone has a reticular rather than a lamellar arrangement and often no sharp distinction can be drawn between the spongy and compact portions. The Haversian canals are numerous and relatively large, and tend to run in circles concentric with the periphery of the bone rather than parallel to its long axis. There are many anastomotic canals which connect the Haversian canals with one another and with the internal and external surfaces of the bone. The number of lamellæ surrounding each Haversian canal, as well as the number of periosteal lamellæ, is less in the infant than in the adult. The fibers of Sharpey on the other hand are more numerous and larger in the infant. The bone corpuscles also are said to be larger in early life.

Bone growth takes place very rapidly in infancy and by the age of two years most of the peculiar characteristics of the long bones of sucklings are lost. According to Gundobin,[7] however, it is not until the age of 12 that the structure of the long bones becomes identical with that of the adult.

In infancy the flat bones of the skull differ considerably in their various parts. At the time of birth the inner and outer tables can be easily recognized in the region of the eminences, where they are separated by a narrow marrow cavity. As in later life the outer table is thicker than the inner. Along the growing margins of the bones, however, the structure is still reticular and remains so for some time after birth. Haversian canals are present in the older parts of the calvarial bones at the time of birth.

The periosteum is from one-third to one-half as thick in the newborn as in the adult (Schulz).[55] During early childhood, at least, there is a definite inner osteogenic layer rich in osteoblasts and containing few connective tissue fibers. The osteoblasts are so numerous in the inner layer of the periosteum of the long bones at birth that they have almost an epithelial arrangement. By the end of the twentieth year the osteoblastic layer is greatly reduced or completely fused with the middle or fibro-elastic layer of the periosteum.

The Skull

The skull at birth (Figs. 84, 85, 86, 87, 180).—The most striking characteristic of the skull of the newborn child is the preponderance of the neural or calvarial portion over the facial. The relation between the two at birth is as 8:1 as compared to the ratio of 2.5:1 in the adult female and 2:1 in the adult male. The calvarium is also much larger in proportion to the base of the cranium than in adult life. The bones of the cranial vault are quite thin and are separated by narrow strips of tough membrane. At the angles of the parietal bones these membranous strips become continuous with the fontanelles. These structures are described in a following section. Each parietal bone and each half of the divided frontal bone presents, near its center, a rounded eminence. These elevations mark the approximate position of former ossification centers. When viewed from above, the frontal and parietal eminences, together with the less noticeable projection of the occipital bone, give the skull an elongated pentagonal outline.

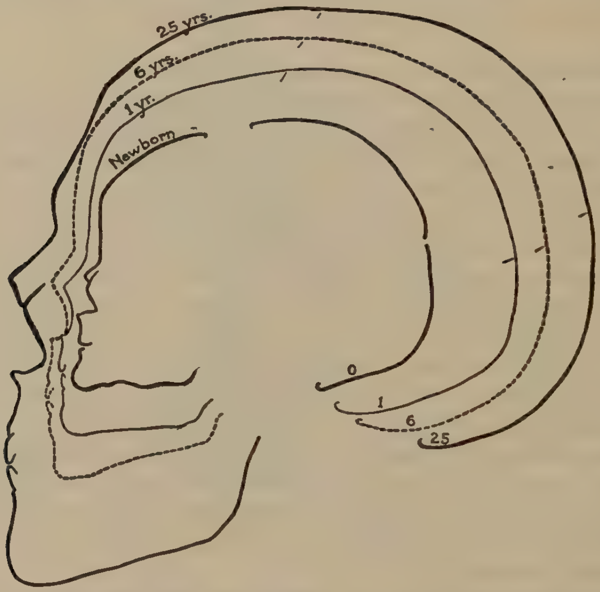

Fig. 85.—A series of median longitudinal sections of skulls illustrating the relative growth of the cranium and facial skeleton from birth to maturity. All specimens one-half natural size. (Slightly modified from Welckler, Arch. f. Anthropol., I, 1866.)

The width of the face is relatively less in proportion to the cranium than in the adult but in comparison to its height it is twice as broad as in maturity. The upper portion of the face is much more completely developed than the lower. The orbits are large and rounded with sharp margins. The nasal aperture is large, broad, and rounded and the inferior nasal spine is well marked. The upper and lower jaws are broad and very low. They present a series of rounded elevations which contain the dental sacs of the milk-teeth.

The base of the skull is small compared to the vault which extends beyond it laterally and posteriorly. Its surface is without marked elevations. The hard palate is short and broad and the choanæ are almost circular. Both the lateral and medial lamina of the pterygoid process are plate-like and extend forward and outward at an acute angle with the base of the sphenoid bone. There are no true bony auditory meati at this time but the ear drums with their surrounding tympanic rings form prominent features of the base of the skull. The foramen magnum is relatively larger in the newborn than in later life and is placed more anteriorly in the base of the skull. In the infant the anterior margin of the foramen magnum lies at a distinctly higher level than the posterior while in the adult the plane of the foramen is almost horizontal. The condyles are not raised above the general surface of the occipital bone and are quite flat both anteroposteriorly and from side to side. As a result, movement at the occipitoatalantoid joint is quite limited in infancy and most movements of the head are brought about through the mobility of the cervical intervertebral joints.

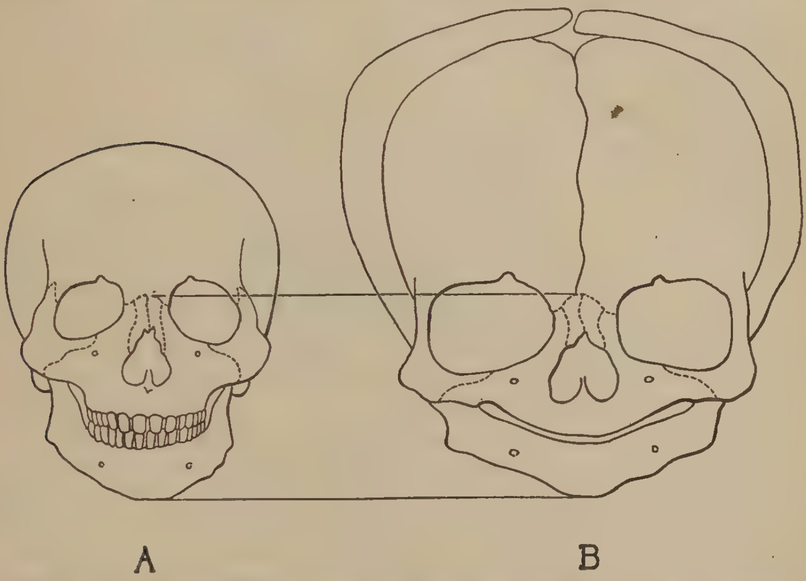

Fig. 86.—A diagram illustrating the post-natal changes in the proportionate height of the cranium and face. A, adult skull; B, skull of a newborn child. The two specimens are drawn so that the facial heights (from nasion to pogonion) are equal. (After Holl.[30])

The Post-natal Development of the Skull (Figs. 85, 86, 87, 181, 186).—The skull as a whole grows relatively less in post-natal life than the other divisions of the skeleton. Between birth and maturity the neural portion increases four or five times and the facial part about 12 times in volume. During the same period the cranial capacity increases about three and one-half times (from about 400 c.c. to 1300 to 1500 c.c.) and the horizontal circumference approximately 50 per cent. (circa 35 cm. to 50 to 55 cm.). Most of this growth takes place in the first two years of life. The development of the skull is intimately associated with the growth of the other structures of the head, particularly with that of the brain and eye-balls, the teeth, and certain of the larger muscles. These structures affect the growth of the skull at quite different periods; the brain and eye-balls mainly during the rapid growth of early infancy, the teeth mainly during the period of establishment of the permanent dentation and the muscles mainly in later childhood and after puberty.

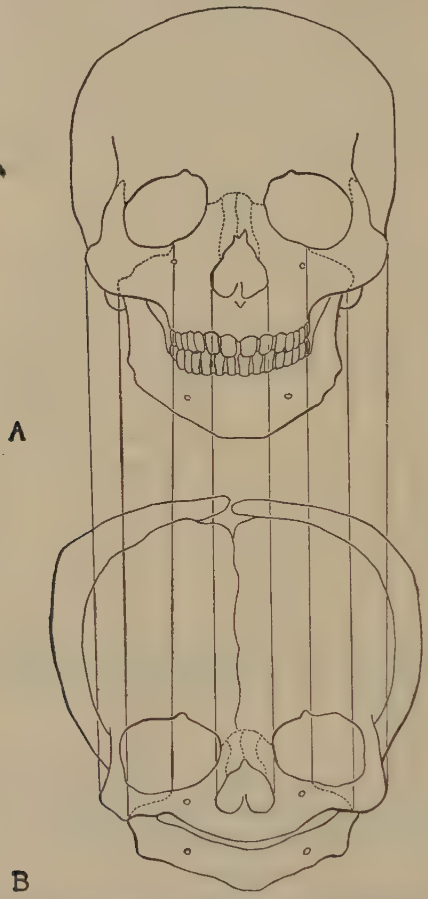

Fig. 87.—A diagram illustrating the post-natal changes in the breadth of the facial skeleton and the cranium. A, adult skull; B, skull of a newborn child. The two specimens are drawn so that the facial breadths (bimalar diameters) are equal. (After Holl.[30])

The methods of Roentgenography have not been applied successfully as yet to the study of post-natal skull development. All of our knowledge of the subject is based either upon measurements of the head in the living or on the examination of prepared skulls. The latter are often warped in drying and may be of uncertain history. Consequently any description of the process can be regarded merely as an outline subject to revision as more data are collected by modern methods. Following Merkel,[41] three general periods can be recognized in the post-natal development of the skull. The first period, in which the skull grows rapidly, is from birth to about seven years. The second, a period of slow growth, is from seven years to 10 or 12 years. The third, in which the rate of growth again increases somewhat, extends from 10 or 12 years to about 19 in the female and a little later in the male. During early infancy all parts of the skull grow rapidly. The cranial capacity increases from about 400 c.c. in the newborn to 700 c.c. at six months, 900 c.c. at 12 months, and about 950 c.c. at 18 months. The horizontal circumference increases in the same period from about 35 cm. at birth to about 47 cm. at 18 months. The growth of the occipital portion of the vault is more rapid than that of the frontal and parietal portions. During this period the facial skeleton grows even more than the cranium so that the relation between the two of 1:8 at birth is reduced to 1:6 in the course of the second year. This growth of the face is due in part to the increase in the size of the orbits, which accomplish over half of their post-natal growth in the first two years of life, and in part to the expansion of the maxillæ. After 18 or 20 months the growth of the skull, although continued, is less rapid. The cranium continues to expand, the vault growing more rapidly than the base up to seven years. The facial skeleton continues to grow more rapidly than the cranium and by five years the relation between the two is as 1:5. Most of the growth of the facial skeleton is in the lower part of the face and is due to the lateral expansion of the hard palate and the development of the maxillary sinus. By the end of the seventh year many parts of the skull, such as the body of the sphenoid bone, the cribriform plate of the ethmoid bone, and the petrous portion of the temporal bone have attained their final size; while other parts, such as the orbits, have almost reached adult dimensions. From 7 to 10 years the skull grows but little, aside from the lengthening of the face which accompanies the establishment of the permanent dentation. From 10 or 12 years to the end of the second decade growth again becomes more rapid. The cranium grows slightly in all directions through the increase in thickness of the bones forming it; and more strikingly anteriorly through the further development of the nasal skeleton and the growth of the upper and lower dental arches. The eminences of the cranium are lost, entirely or in part, and the various muscular ridges become prominent. As a rule these changes of the third period of skull development are less extensive in the female than in the male skull.

The Fontanelles (Figs. 84, 88, 89, 90).—The fontanelles are membranous plates which at birth and for a variable period thereafter bridge the gaps occurring between the angles or margins of certain bones of the cranium. In structure they consist of three layers of membrane; an outer which is continuous with the pericranium, an internal which is continuous with the endocranium, and a middle which is composed of a highly vascularized connective tissue which is later replaced by the ingrowth of bone.

Six fontanelles are normally present at birth. Two of these are single and median in position. These are the frontal or great fontanelle, which occupies a diamond shaped space between the two parietal bones, and the two (separated) halves of the frontal; and the occipital or lesser fontanelle which lies between the posterior median angles of the parietals and the upper angle of the occipital bone. The lateral fontanelles consist of two pairs. The anterior, stephanal, or sphenoid fontanelle is generally bounded by the squamous portion of the temporal bone, the greater wing of the sphenoid bone, the sphenoid angle of the parietal bone, and the lateral and posterior angle of the frontal bone. The posterior, lateral, or mastoid fontanelle lies between the mastoid angle of the parietal bone, the mastoid and squamosal

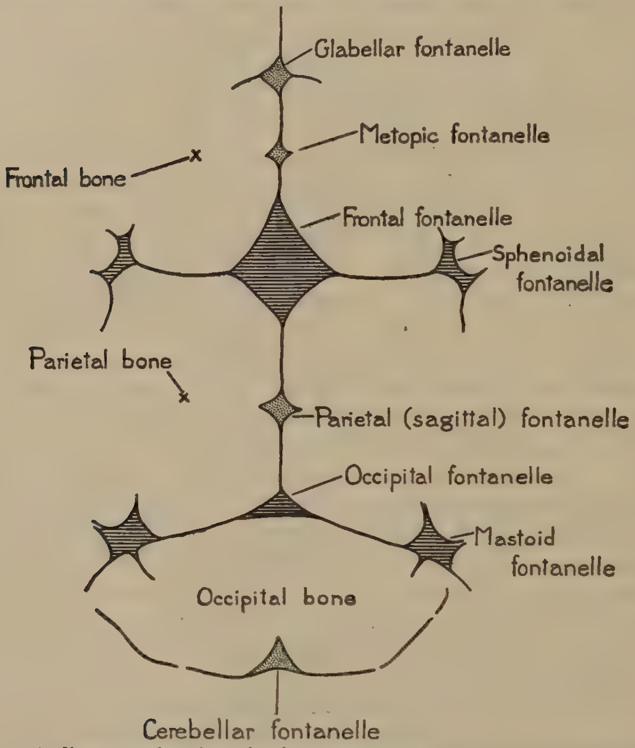

Fig. 88.—A diagram showing the form and position of the constant and principal accessory fontanelles at birth. The constant fontanelles are shaded in cross-lines; the accessory fontanelles are shaded in stipple.

portions of the temporal, and the supra-occipital portion of the occipital bone. The mastoid fontanelles are often shaped like an inverted L with the horizontal limb of the L extending forward over the superior margin of the temporal bone and the vertical one directed downward medially to come in contact with the basi-occipital portion of the occipital bone.

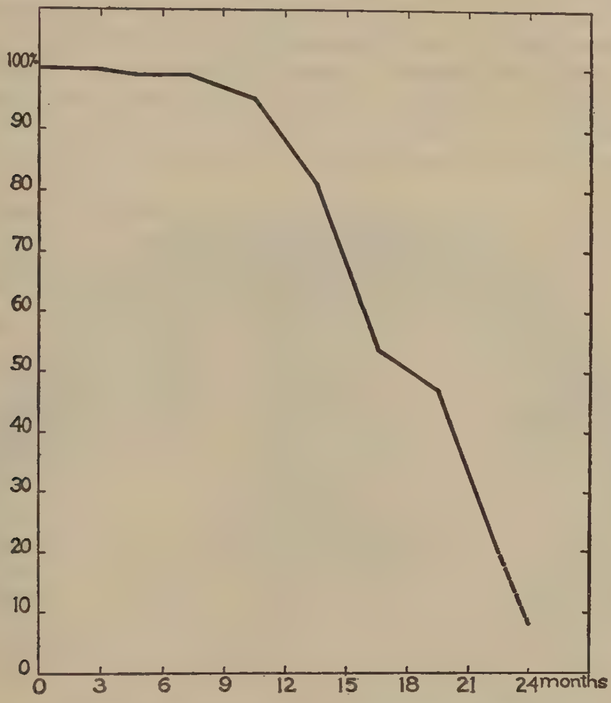

Fig. 89.—A curve showing the average percentage of open frontal fontanelles, as determined by palpation, in each trimester from birth to two years. (Based upon the data presented in table 2. Total number of cases, 945.)

Besides these constant fontanelles numerous accessory ones occur occasionally in various parts of the cranium. Frasseto[23] has listed nearly 20 of these structures but only a few are at all common or liable to be of practical importance. All of the more important accessory fontanelles are located along the sagittal suture. The glabellar fontanelle is a very unusual one located between the two halves of the frontal bone above and the two nasal bones below. When of any size it is commonly associated with other serious anomalies of the nasal skeleton. The metopic fontanelle is located just above the glabellar in the metopic suture which separates the two halves of the frontal bone and is found in about one skull in six of children under one year of age. As a rule it is an insignificant cleft but it may acquire some size when present in cases of hydrocephalus. It is sometimes confluent with the frontal fontanelle and is regarded by Schultz[54] as as anterior extension of this structure. The sagittal fontanelle lies between the medial margins of the two parietal bones in a line drawn between the two parietal eminences. It is diamond shaped or triangular in outline and is palpable in about 5 per cent. of all newborn children. The cerebellar fontanelle is a small gap in the upper margin of the foramen magnum caused by the failure of development of a small ossicle which generally forms a part of the occipital bone in this region. A cerebellar hernia may protrude through this space when it is of unusual size. Figure 88 is a diagram of the calvarium as seen from above and indicates the position of all the normal and the more common accessory fontanelles.

It is only within recent years that the post-natal involution of the fontanelles has been carefully studied. The older writers (Elsässer, Roger and Friedleben) were of the opinion that the greater fontanelle increased in size for several months after birth, an opinion still to be found in some of our texts today. This conclusion however was based upon studies of children of whom some were premature or rachitic. All modern studies show that, with the exception of prematures, the frontal fontanelle, beginning some weeks after birth, undergoes a regular course of involution. Some statistics of this process are shown in Table 2, and Fig. 89 is a graphic representation of a part of these data. The average diameter of the fontanelle in a full-term newborn, as determined by Elsässer's method* is approximately one inch (25 mm.) being a little greater in boys than in girls. The surface area is approximately 3.75 square cm. although it is difficult to determine it exactly at this time because of the continuity of the fontanicular space with the gaping coronal and sagittal sutures. The reduction of this area goes

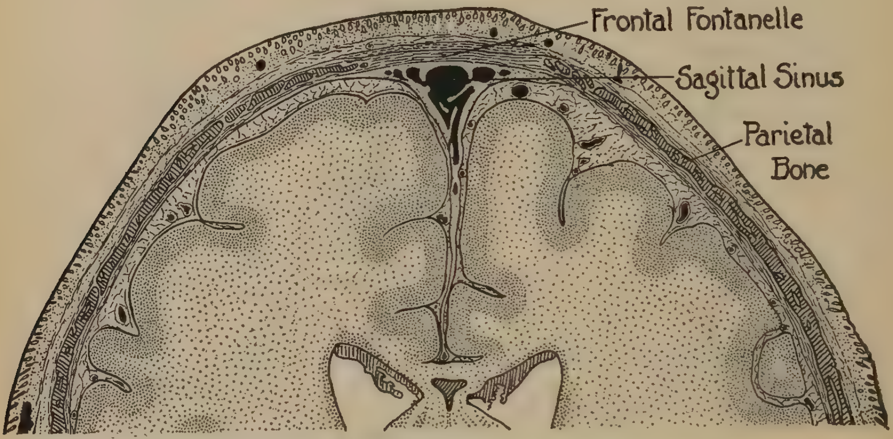

FIG. 90.—Frontal section of the frontal fontanelle, sagittal sinus and adjacent structures in a full-term newborn child.

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* Elsässer's diameter.—The average of the two oblique diameters taken from the middle of the fontanicular margin of one frontal bone to the middle of the fontanicular margin of the parietal bone of the opposite side.

on steadily in normal children although at widely varying rates in different individuals and apparently more rapidly in girls than in boys. As will be seen from the table, approximately 1 per cent. of apparently normal children show complete obliteration of the great fontanelle in the third trimester of post-natal life and 4.5 per cent. in the fourth trimester. From the beginning of the second year the rate of obliteration increases rapidly and by the end of the second year the fontanelle is obliterated, so far as can be determined by palpation, in over 90 per cent. of all normal cases. As the material upon which these averages are based was obtained to some extent from the poorer classes of the larger European cities it is probable that the percentages of obliteration are all somewhat low for the better nourished and more rapidly growing American children.

Table 2.—The Post-natal Involution of the Frontal Fontanelle (Based on the Data of Roger, Kassowitz, Cohn, Rohde and Nikiforoff)

Age	Average diameter (in centimeters both sexes)	Average area (in square centimeters, males)	Average area (in square centimeters, females)	Percentage of fontanelles closed
0 to 3 months	2.6	3.70	3.65	0.0
3 to 6 months	2.4	3.03	2.92	0.3
6 to 9 months	2.1	2.43	2.60	1.1
9 to 12 months	1.8	1.55	1.45	4.5
12 to 15 months	1.2	1.20	1.22	18.6
15 to 18 months	0.55	1.08	0.97	46.2
18 to 21 months	0.31	....	....	53.5
21 to 24 months	0 08	....	...	80.0

Our data regarding the involution of the other fontanelles are much less extensive and, except for the sagittal fontanelle, are based upon observations on dried skulls. The sagittal fontanelle generally closes in the first three months of post-natal life although it may, in exceptional instances, remain open until the eighth month. The time of obliteration of the metopic fontanelle is variable but it is always completed by the end of the first year. The occipital fontanelle is already obliterated in nearly a third of all full-term newborn children and the process is usually completed by three months after birth. The sphenoidal fontanelle closes in the first six months of post-natal life. The mastoid fontanelle is generally open until the end of the first year but is always closed by 18 months. There are no data of value on the time of obliteration of the glabellar and cerebellar fontanelles.

The obliteration of the fontanelles is generally brought about by the progressive ingrowth of the edges of the membranous bones which bound them. Occasionally, however, separate ossific centers may arise in the fontanellar membranes and form distinct bones which occupy all or a part of the original fontanellar space. In these cases the obliteration of the fontanelle may be considerably hastened.

The Post-natal Development of Certain Cranial Bones.—Certain of the bones of the child's skull differ sufficiently from those of the adult to warrant brief individual descriptions.

The frontal consists of two lateral halves which are separated by a median (metopic) suture. These two masses generally begin to unite in the second year and their fusion is generally completed between the sixth and eighth years, although sometimes much later. The suture remains throughout life in about 8 per cent. of European skulls. The frontal eminences are well marked in early life while the superciliary arches and frontal spine are practically lacking.

The sphenoid, at birth, consists of three separate parts; a middle portion which represents the body, the lesser wings, and the lingulæ; and a pair of lateral masses representing the greater wings and the pterygoid processes. In about 1 newborn skull in 20, the body of the sphenoid is pierced by a small canal which extends downward from the floor of the hypophyseal fossa. This canal ordinarily contains only a small amount of connective tissue and a few small vessels, but in rare cases small nodules of hypophyseal tissue may be lodged within it. The body of the sphenoid is composed of spongy bone at the time of birth and for several years thereafter, for the sphenoidal sinus, as a rule, does not actively invade the bone in early infancy. The body and lateral masses of the sphenoid unite in the first year.

The occipital at birth consists of four bony masses: the supraoccipital, two lateral occipitals, and the basioccipital. These are arranged in a ring around the foramen magnum and are united by cartilage. The cartilage between the lateral occipitals and the supraoccipital has some flexibility at the time of birth and from its supposed movement during labor, is sometimes termed the obstetric joint. The upper and thinner part of the supraoccipital is often partially separated from the lower portion by a suture, the sutura mendosa. The supraoccipital and lateral occipitals usually begin to fuse in the second year. The lateral occipitals generally unite with the basioccipital in the third or fourth year. The fusion of all these elements may be delayed until the seventh year or even later. Ossific union between the basioccipital and the body of the sphenoid begins, as a rule, shortly after puberty and is completed early in the third decade.

Only the lateral masses of the ethmoid are formed in bone at birth. The remainder of the bone is still cartilaginous. The perpendicular plate ossifies in the first year, the cribriform plate in the second and the crista galli between the second and fourth. These three elements unite as they ossify and join with the lateral masses in the sixth year.

The mandible of the newborn consists of lateral bony halves which are united at the symphysis by a mass of cartilage. Within this cartilage are several bony particles known as the mental ossicles. The lateral halves of the bone unite in the latter part of the first or the early part of the second year. The mental ossicles usually begin to join the main bone in the first year and are always completely fused with it by the end of the third year.

The body of the mandible is relatively large at birth and its upper two-thirds is occupied by the crypts of the deciduous and certain of the permanent teeth. The rami are short and broad and are set at an angle of about 140° to the body.

There are several different concepts of the method of growth of the lower jaw and the inferior dental arch. The most generally accepted one, which is outlined here, was first developed by John Hunter and was subsequently elaborated by Tomes (the elder), Humphry, and others. According to this view, the growth of the mandible in length, *i.e.*, in the anteroposterior dimension, is brought about mainly by the apposition of bone along the hinder margin of the ramus. As bone is deposited at this point it is resorbed along the anterior margin of the ramus and the position of this structure is thus shifted backward and outward. At birth the anterior margin of the ramus lies at the level of the first permanent premolar and the germs of the permanent molars are embedded in the base of the coronoid process. With the resorption of the anterior margin of the ramus, these tooth-germs are uncovered and the posterior part of the dental arch is established. As the ramus is built up posteriorly, its form is gradually remolded and the angle between it and the body is reduced from about 140° at birth to about 130° at the end of the first period of childhood and about 120° in the adult. A smaller part of the length-increase of the lower jaw

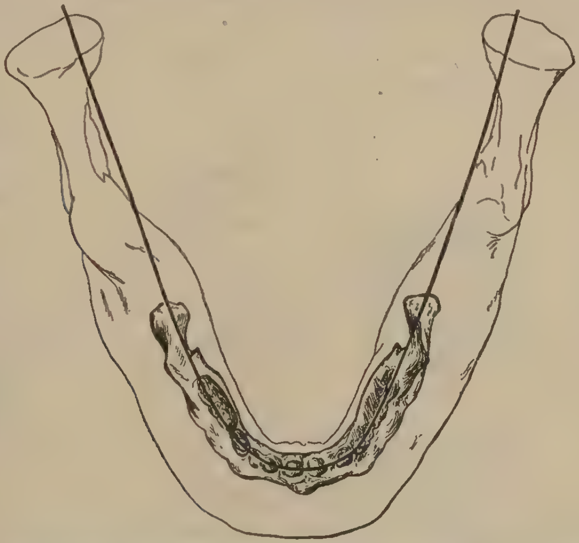

Fig. 91.—A diagram illustrating the post-natal growth of the mandible. The smaller shaded specimen is the jaw of a nine months fetus; the larger specimen, drawn in outline, is the jaw of an adult. The specimens are drawn to the same scale and are superimposed. (After Tomes, Dental Anatomy, 1898.)

takes place anteriorly through the addition of bone on the labial surfaces of the mandible and the formation of the alveolar processes.

The post-natal growth of the ramus in height takes place mainly through the addition of new bone along its superior border. The vertical increase in the body is due in part to formation of the alveolar borders and in part to the growth of its basal portion. The alveolar borders are formed as the deciduous teeth are erupted. When these teeth are shed their alveolar borders are absorbed and new borders are built up around the permanent teeth. The base of the jaw, *i.e.*, that portion lying below the level of the mental foramen, grows even more, relatively, than does the alveolar margin. This growth is due mainly to the addition of bone along the inferior margin; it takes place throughout infancy and childhood.

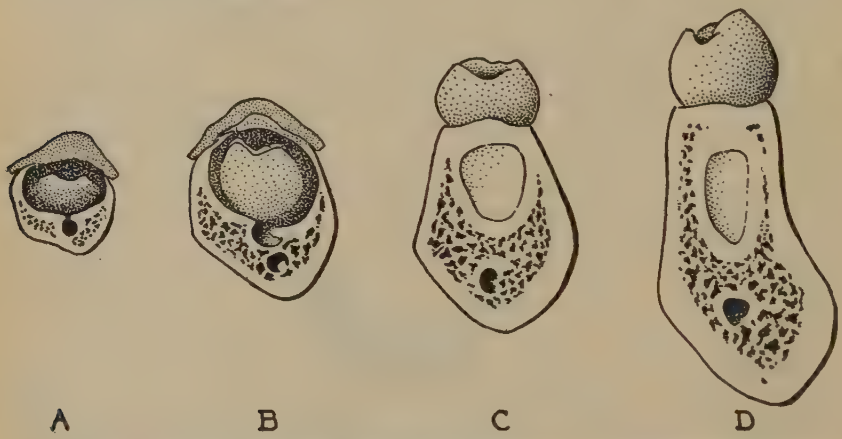

Fig. 92.—A series of sections illustrating the growth in thickness and height of the body of the mandible; the change in position of the inferior alveolar (dental) canal; and the formation of the alveolar margins. A, five months fetus; B, child at term; C, child of three years; D, adult. The sections are all taken at the level of the second deciduous molar. (After Vallois et Bennejeant.[133])

In early infancy there is some increase in the transverse diameter of the lower jaw through the formation of bone at the symphysis. However the greater part of the post-natal increase in this diameter is brought about through the deposit on the outer surfaces of the mandible and by the lateral as well as posterior growth of the rami.

The maxilla of the newborn is extremely low and broad and the frontal process is relatively larger than in the adult. The alveolar border contains five large fossæ for the deciduous teeth. A fissure, the sutura notha, extends across the palatine process from the incisive foramen to the plate of bone separating the fossæ of the lateral incisor and the deciduous canine tooth. This marks the boundary between the maxilla proper and the premaxillary bone. The infra orbital canal communicates freely with the orbit above. The maxillary sinus (antrum of Highmore) is represented by a long narrow recess on the medial side of the bone.

The post-natal growth of the maxilla is illustrated by the diagram shown in Fig. 93. The increase in the vertical diameter of the bone is due mainly to the expansion of the maxillary sinus and the development of the alveolar margins. Most of the growth in length comes about through the deposition of bone at the posterior end of the maxilla. As the maxillary sinus invades this part of the bone the permanent molars are carried downward and backward and the posterior part of the upper dental arch is established.

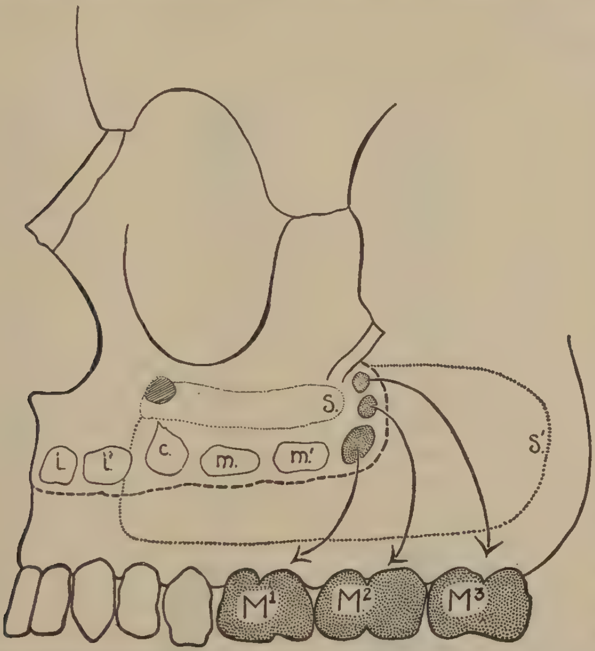

Fig. 93.—A diagram illustrating the post-natal changes in the form of the maxilla and the growth of the superior dental arch. The broken line represents the outline of the maxilla at birth. The adult bone is drawn in solid line. The permanent molars are represented in stipple. c., Deciduous canine; i.–i′, deciduous incisors; m.–m′, deciduous molars; M^1–M^3, permanent molars; s., maxillary sinus at birth; s′, maxillary sinus at maturity. (After Keith, Human Morphology and Embryology, 3rd ed., London.)

The Free Vertebral Column (Fig. 94)

The vertebral column may be divided into the free portion consisting of the cervical, thoracic, and lumbar vertebræ, which will be considered in this section; and the sacrum and coccyx which can best be described in connection with the pelvis.

The average length of the free vertebral column in the full-term newborn child is 19 or 20 cm. It is equal to approximately 40 per cent. of the total body-length. During the first two years of life it grows rapidly, increasing to about 45 cm. Thereafter the relative rate of growth becomes much slower, the vertebral column attaining a length of about 50 cm. at the time of puberty and its final length of from 60 to 75 cm. about the twenty-second year in females and the twenty-fourth year in males.

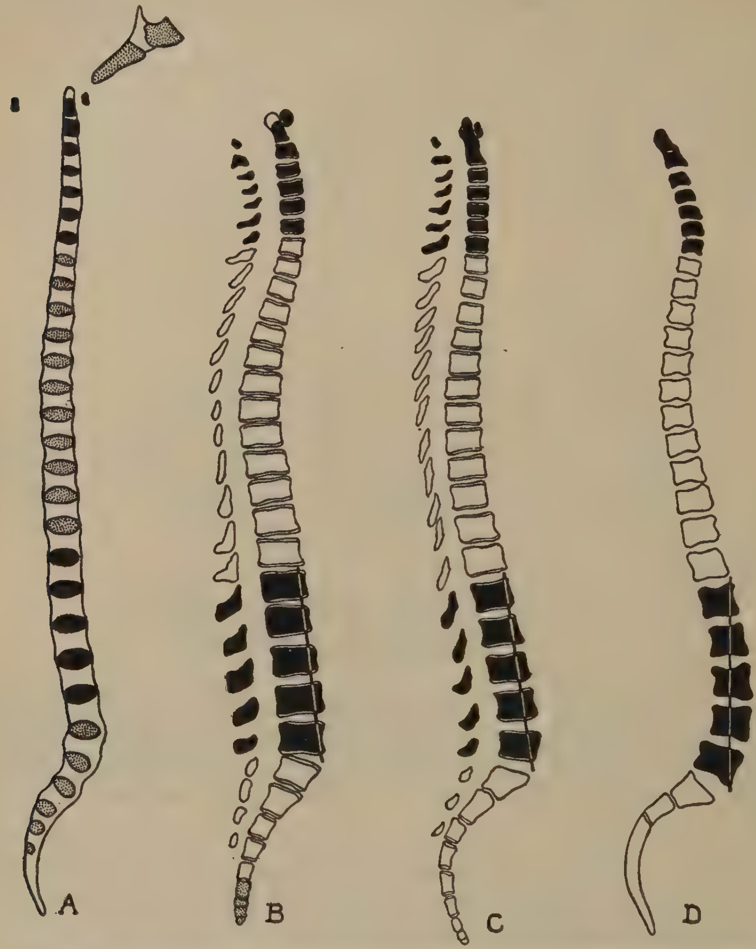

Fig. 94.—Median sections of the vertebral column at different ages illustrating the development of the normal spinal curvatures. A, newborn; B, male of six years; C, female of 13 years; D, adult male. All specimens drawn to the same size (from the axis to the top of the coccyx). The lumbar and cervical vertebræ are represented in solid black. (After Cunningham.[19])

The post-natal lineal growth of the column in childhood is due mainly to an increase in the size of the primary centers of the bodies of the vertebræ; the lineal increase after puberty is brought about mainly by the formation and growth of the epiphyses of the vertebral bodies.

The relation that the various segments (cervical, thoracic and lumbar) of the free vertebral column bear to the whole, differs somewhat in the infant and the adult. In the newborn the cervical part forms approximately one-fourth, the thoracic part one-half and the lumbar part one-fourth of the entire free spine. In the adult the thoracic portion continues to form approximately one-half of the total free spine but the lumbar portion is increased to nearly one-third and the cervical portion reduced to one-fifth or one-sixth of the whole. Thus the short thick neck of the infant is due to the abundance of adipose tissue in this region and not to its skeleton which is, in fact, relatively longer than in the adult. The time at which these relational changes take place seems to be quite variable but the process of shifting from the newborn to the adult relations is most rapid in the first three years of life.

The development of the cervical and lumbar curves of the spine is a post-natal process. In the newborn child, resting on its back, the spine forms a single gentle curve extending from the first cervical to the last lumbar vertebra, with its concavity directed anteriorly. The vertebral column at this time is still so plastic that if it is dissected free of the body it may easily be bent into a ring with the axis and the last lumbar vertebra in contact (Dwight and Rotch[5]). A cervical curve appears when the infant begins to lift its head but neither at this time nor later does it become a fixed one. The lumbar curve appears at the end of the first or beginning of the second year as the child begins to walk. It forms very slowly and throughout childhood and adolescence it may be effaced by stretching the spine. The formation of the cervical and lumbar curves is due primarily to muscular action associated with the elevation of the head and the assumption of the erect posture. Later the lumbar curve is fixed, in a measure, by the anterior thickening of the third, fourth, and fifth lumbar vertebræ and the intervertebral discs separating them. While this process begins in childhood it proceeds very slowly until maturity.

At the time of birth each typical vertebra consists of a bony body and two neural arches or lamina. These three separate osseous masses are connected with one another by hyaline cartilage, and a film of the same material covers the inferior and superior surface of the body. The two lateral masses representing the vertebral arch fuse in the medial line in the first year of life. This process begins in the vertebræ of the lumbar region and proceeds cranially. The fusion between the arches and the vertebral bodies begins in the fourth year and is generally completed by the end of the sixth. It starts with the cervical vertebræ and proceeds caudally. The epiphyses of the vertebræ appear after puberty. In the seventeenth year or later epiphyseal centers are formed in the cartilages of the transverse and spinous processes and on the superior and inferior surfaces of the vertebral bodies. A separate series of centers are also formed for the mammillary processes of the lumbar vertebræ. All of these epiphyses commonly join with the main mass of the vertebra between the twentieth and twenty-fifth year. The reader will find the regional modifications of the process of vertebral ossification described in detail by Poirier and Charpy (Traité d'Anatomie Humaine, T. I.) and by Bardeen.[18]

The atlas of the newborn consists of two osseous masses which represent the posterior arches and the lateral masses of the fully formed bone. These are united in front by a rounded bar of cartilage and behind by a thin plate of the same material. During the first year or two, centers appear in the anterior arch. The two posterior masses fuse with the anterior one in the third or fourth year; they join with one another across the posterior median line between the fifth and ninth years.

The axis or epistropheus at birth consists of two median bony masses; one in the body, and one in the odontoid process or dens; and of two lateral ones representing the vertebral arch. The lateral halves of the arch join across the posterior median line in the first year and the arch, dens, and body fuse into a single bone between the third and sixth years. A cranial epiphysis for the dens appears in the second year and a caudal one for the body in the seventh. The former joins the bone in the twelfth, the latter in the twentieth year.

The bodies of all the "typical" vertebræ more than double their diameters both transverse and sagittal, in the course of post-natal life. The growth of the bodies of the vertebra may be divided into three periods; first, from birth to three years during which from one-half to two-thirds of the entire post-natal increase occurs; second, from 3 to 16 years, a period of little if any growth; third, from 16 years to maturity during which approximately one-third of the total growth takes place. The growth of this last period is entirely epiphyseal.

THE PELVIS

The Pelvis as a Whole (Figs. 95, 96, 97, 151, 159).—The pelvis of the newborn differs from that of the adult in a number of particulars. Some of the more striking are listed below.

The general form of the newborn pelvis is distinctly conical. The length is somewhat greater in proportion to the greatest transverse and the anteroposterior diameters than in the adult.

The pelvic cavity is much smaller relatively than in the adult. It is conical or infundibulaform and the linea terminalis is poorly marked. The inlet, or superior aperture, of the lesser pelvis approaches more nearly a true circle than in later life but even at birth the transverse diameter is slightly greater than the anteroposterior. The dimensions of both the lesser pelvic cavity and the pelvic outlet are smaller in proportion to the pelvic inlet than in the adult.

The sacrum forms a greater proportion of the pelvic circumference than in the adult. It is less depressed between the ilia than in later life, and the sacral prominence is less marked and lies at a higher level. A second promontory may be indicated at the level of the linea terminalis. The sacro-pelvic angle is marked in the newborn, but the longitudinal and transverse concavities are hardly indicated.

The ala of the ilia are thick and rounded and extend upward abruptly. The iliac fossæ are present but are very shallow.

The acetabula are very large at birth but are much shallower than in later life.

The obturator (thyroid) foramina are relatively small and are placed nearer together than in the adult.

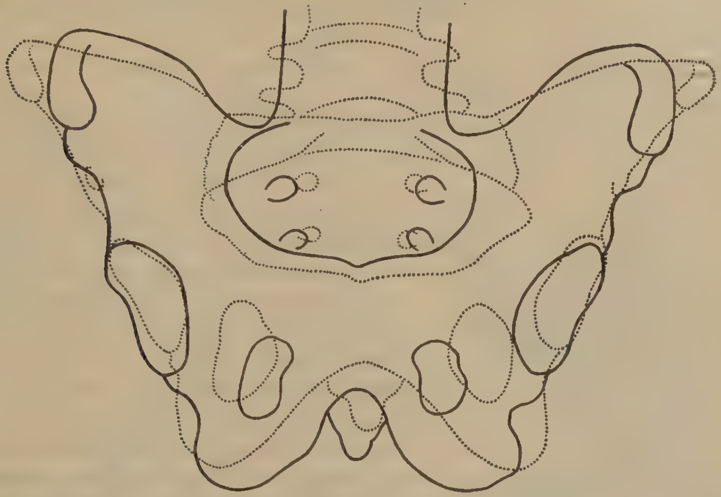

Fig. 95.—An outline drawing of the pelvis, as seen in anterior view, of a male newborn child, with the outline of an adult male pelvis drawn to the same size and superimposed upon it. The newborn pelvis is drawn at natural size and in solid line; adult pelvis is represented in broken line. (After Merkel, Handb. d. topogr. Anat.)

The pelvis is more vertical in position at birth than later. The plane of the superior aperture forms an angle of 80° with the horizontal as compared with 60° in the adult. The symphysis is also placed more vertically.

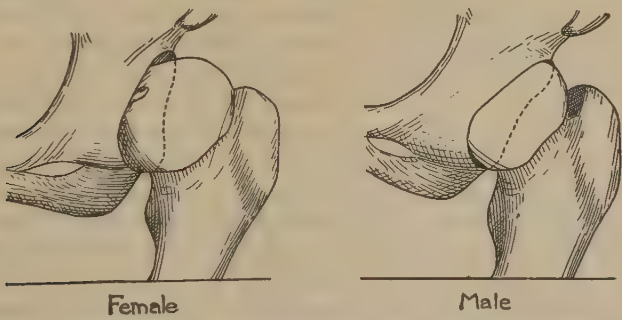

Fig. 96.—Dissections of the hip-joints of male and female newborn children showing the differences in the degree of inclusion of the head of the femur in the acetabulum in the two sexes at birth. (After LeDamany.[38])

Sexual differences in the pelvis can be made out as early as the fourth month of fetal life and are quite marked at birth. The pelvis of the newborn male is larger than that of the female; the sacrum is relatively wider; the ala are less vertical, and the subpubic angle is more acute (58° in males and 63° in females according to the measurements of Le Damany[38]). In girls, the acetabulum is almost vertical in position and only the lower part of the head of the femur is lodged in the cavity—a fact which explains the greater relative frequency of congenital dislocations of the hip in females (see Fig. 97 and further remarks under femur).

According to Hasse,[27] the bony pelvis shows a slight but constant asymmetry at birth.

During the first two years of life the pelvis grows rapidly in all dimensions. From two years to the end of the first decade the rate of growth is much less rapid. The growth rate increases again in the second decade and by the end of this time the pelvis has attained almost its adult dimensions although many of the pelvic epiphyses do not unite with their main bones until the twenty-fifth year.

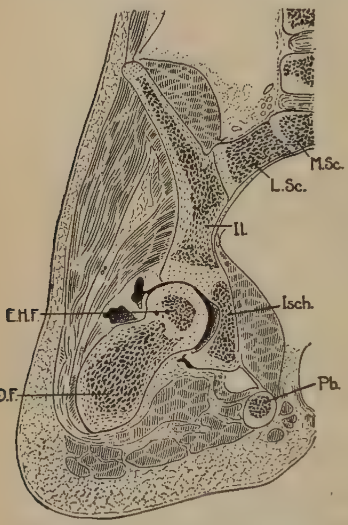

Fig. 97.—A frontal section of the right half of the pelvis of a girl nine years old. D.F., diaphysis of femur; E.H.F., epiphysis of head of femur; Il., ileum; Isch., ischium; L.Sc., lateral centers of the sacrum; M.Sc., median centers of the sacrum; Pb., pubis.

Until the infant assumes the erect position the pelvis changes very little in form. As this position becomes the habitual one the sacrum begins to descend between the ilia, and the promontory is slowly established. The increase in the transverse diameter of the pelvis is brought about mainly by the growth of the lateral parts of the sacrum and the posterior parts of the ilia. Growth also takes place along the line of apposition of the three divisions of the innominate bone in the acetabulum; but there is comparatively little growth, at least in males, at the symphysis pubis. The pelvic growth which occurs after puberty is practically all epiphyseal.

The sexual differences of the newborn pelvis, aside from that of size, are lost during the period of early rapid growth and do not reappear until after the close of the first decade. At birth and during the first decade the pelvic measurements of boys are greater than those of girls. After the tenth year the reverse is generally the case.

The growth of the pelvis as demonstrated by external measurements on normal living children is shown in Table 3 which is based upon some of the more important collections of data on the subject. The measurements in the lowest column of the table are of only limited value because of the small number of cases. The reader is recommended to the papers of Le Damany[37, 38] and Merkel[41] for recent discussions of the postnatal differentiation of the pelvis.

Table 3.—The Diameters of Pelvis as Determined by Measurements of Living Children

(Summarized from the Tables of Klein, Konikow and Tatewossoff. Averages Calculated to Nearest Millimeter)

Age	Number of cases		D. Baudeloque centimeters		D. Spinarum centimeters		D. Cristarum centimeters		D. Trochanterica centimeters	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
Newborn	17	22	6.6	6.2	7.2	6.9	7.9	7.5	9.1	9.0
1 to 2 yrs	17	18	9.4	11.4	11.8	11.4	12.8	12.6	14.8	14.0
4 to 5 yrs	16	16	10.7	10.8	14.7	14.5	16.7	16.4	17.8	17.5
9 to 10 yrs	20	16	13.4	13.9	18.0	18.2	20.4	19.9	21.7	21.1
14 to 15 yrs	20	19	15.6	17.2	20.9	22.9	23.4	24.8	26.0	27.3
19 to 20 yrs	3	3	17.3	19.3	23.3	25.5	29.0	28.5	31.3	30.5

Ossification of the Individual Bones of the Pelvis (Figs. 84, 97, 151, 152, 155).—The innominate bone is really a complex composed of three main bones, the ilium, ischium, and pubis; one or more minor ones (the ossa acetabuli); and a number of epiphyses. The ossification center of the ilium appears in the ninth week of fetal life; that for the ischium about the middle of the third fetal month; and that for the pubis in the fourth or fifth fetal month. At the time of birth the superior ramus of the pubis, the inferior ramus of the ischium, and the greater part of the body of the ilium are formed of bone. The three bony masses are separated by a broad Y-shaped strip of cartilage which forms the greater part of the floor of the acetabulum. The rami of the ischium and pubis unite in the seventh or eighth year. The margins of the three main bones gradually encroach upon the cartilage of the acetabulum in which one or more separate ossification centers appear between the ninth and twelfth years. The three main bones and the acetabular centers join one another in the fourteenth to sixteenth year. Epiphyses for the iliac crest (three or more), tuberosity of the ischium, ischial spine, and the anterior inferior iliac spine appear soon after puberty. One or two epiphyses for the symphysis pubis appear between the eighteenth and twentieth years. The epiphyses fuse with the main mass of the bone between the eighteenth and twenty-fifth year. The later age changes in the pubic bone are discussed in detail by Todd (Am. Jour. Phys. Anthropol., III, IV).

The sacrum consists of five segments, each of which corresponds to a vertebra. These segments are separate at the time of birth and each contains five centers corresponding to the body, and the neural and the costal centers of the free vertebræ. The costal and neural centers join those of the body between the second and sixth years and the neural centers fuse medially between the seventh and fifteenth years. Epiphyses for the body of each segment appear about puberty, and those for the spine in the eighteenth year. Between the eighteenth and twentieth year a lateral epiphyseal plate, which represents a large number of fused epiphyses, is formed on either side of the sacrum. The segments of the sacrum begin to consolidate from the base upward at puberty, and the various epiphyses join the body of the bone about the twenty-fifth year. A detailed description of the development of the epiphyses of the sacrum will be found in a recent paper by Fawcett.[22]

The body of the first segment of the coccyx ossifies in the first year; that of the second between the sixth and tenth years, the third before, and the fourth after puberty. Two epiphyses are formed for each segment. The coccyx consolidates from the base upward in middle life.

THE THORAX

The Thorax as a Whole (Figs. 84, 121, 168, 169).—The thorax of the newborn has the form of a truncated cone, broad at its base and slightly flattened anteroposteriorly. The posterior wall of the thorax in the newborn is as long in proportion to the trunk as in the adult but the sternum is much shorter both in proportion to the thoracic spine and to the trunk. The superior margin of the sternum lies opposite the body of the second thoracic vertebra, while the tip of the xyphoid process is at the level of the lower part of the ninth or the upper part of the tenth thoracic vertebra. The ribs are less curved and their position is more horizontal than in the adult.

The horizontal circumference of the thorax, at the level of the nipples in newborn children with respiration completely established, is 34 to 35 cm. Linzenmeier[290] found that the average circumference in 40 full-term children before the first inspiration was 30 cm. and after the first inspiration 31.2 cm. It is evidently several days after birth before the chest increase which is dependent on the establishment of respiration is entirely completed. During the first year the circumference of the thorax increases approximately 30 per cent. and in the second year 10 per cent. Thereafter the rate of increase is much slower and it is not until the end of childhood that the horizontal chest circumference is double that of the newborn. With puberty a second period of rapid growth sets in and lasts until 19 or 20 years.

The thorax of the newborn appears almost circular in cross-section because of the relatively great antero-posterior diameter. In the early embryo the thoracic index* is as high as 185 but it declines rapidly during fetal life and at birth is about 90. In the first year it drops to approximately 80 and thereafter more slowly until at eight years it is about 70. There is little change in the index from this time until puberty when it again rises slightly and, according to the measurements of Rodes,[49] lies between 72 and 75 in early maturity. The thoracic index undergoes its greatest reduction during fetal life when gravity cannot be a factor in the change. After the child begins to walk however this force may have some influence on the reduction of the index.

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* Thoracic index.—The per cent. which the antero-posterior diameter of the thorax forms of the transverse diameter at the same level. The index is sometimes determined from measurements at the level of the nipples but more commonly from measurements at the level of the tenth rib. A detailed consideration of the changes in the thoracic index at birth will be found in a recent paper by Scammon and Rucker (Am. Jour. Dis. Child., XXI (1921) p. 552.

Ossification of the Bones of the Thorax.—At birth the sternum is a flexible strip of cartilage containing a variable number of centers of ossification. The manubrium usually contains one main center and sometimes one or two smaller ones situated below the main mass. The body consists of four segments, the ossification of which is very irregular. Often the upper segment contains a single center while the centers of the lower segments are generally paired. Ossification does not begin in the lowest segment until after birth. The segments of the sternum fuse from below upward. The process begins before puberty and is generally completed early in the third decade. Ossification of the xyphoid process begins in the second period of childhood.

The shafts of the ribs are ossified early in the fourth fetal month. The final relative lengths of the bony ribs and costal cartilages are established some time before birth. Each typical rib has three epiphyses; one for the head and two for the tubercle. These are formed about the time of puberty and join the shaft of the bone early in the third decade. The epiphyses of the tubercle join first.

Development of the Bones of the Extremities

Our knowledge of the development of the bones of the extremities has been entirely recast in recent years through the application of the Schultze and Spalteholtz clearing methods and by the use of the Röntgen ray in the study of living material. The following account is based principally on studies with these methods by Mall,[39] Bade,[17] Hasselwander,[28] Puyhaubert,[47] Freymond,[24] Pryor[44, 46] and Rotch.[52, 53]

As a considerable portion of this section deals with the formation of epiphyses and their fusion with their respective shafts in long bones, the following list of rules which have been found to apply to these processes is included here.

(*a*) The formation of the center or centers for the diaphysis always precedes the appearance of the centers for the epiphyses.

(*b*) When a bone has two epiphyses the epiphysis which is the second to ossify is the first to unite with the diaphysis (not true of the fibula).

(*c*) When an epiphysis has more than one center these centers unite with one another before they join the diaphysis.

(*d*) In long bones the first epiphysis appears in the larger extremity (not true of the ulna).

Superior Extremity (Figs. 84, 97).—The clavicle is the first bone in the body to ossify. Two centers for the shaft appear in the sixth week of fetal life and fuse almost at once. The clavicle has a single sternal epiphysis which appears between the eighteenth and twentieth years and fuses with the shaft between the twentieth and twenty-fifth years.

The main ossification center for the body of the scapula appears in the eighth week of fetal life. At birth this forms a bony plate which is surrounded, except on the axillary and superior borders, by a peripheral band of hyaline cartilage. At this time the coracoid process, a part of the acromial process, and the neck of the bone are cartilaginous. A separate center appears in the coracoid process during the first year and this fuses with the body of the bone at puberty. A small subcoracoid center appears in the tenth to twelfth year. A series of epiphyses, for the vertebral border and inferior angle, the acromium and coracoid processes, and the surface of the glenoid fossa appear between the fifteenth and eighteenth years. These join with the main bony mass between the twenty-first and twenty-fourth years.

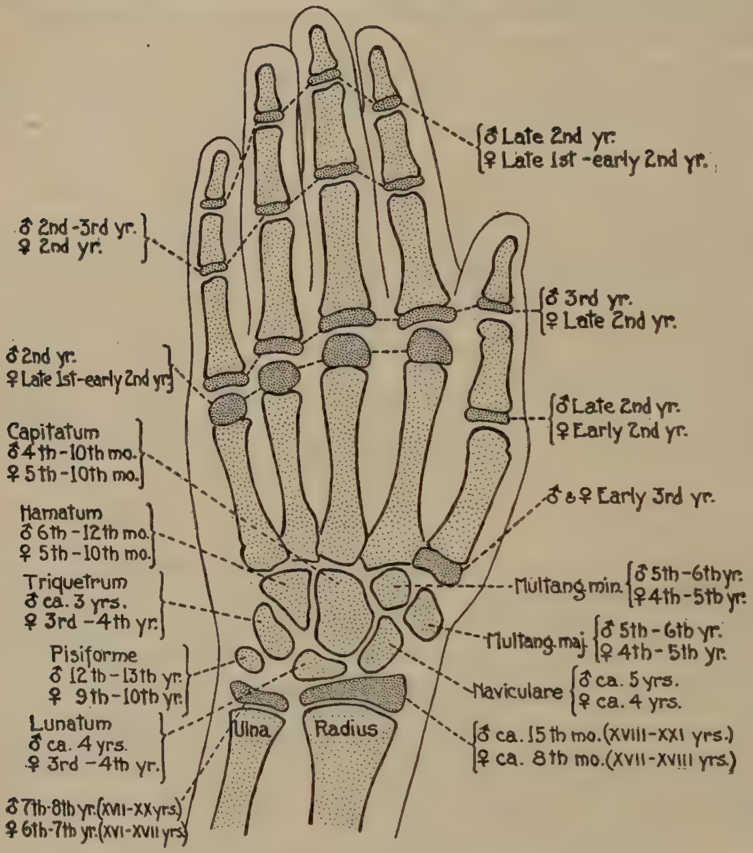

FIG. 98.—A diagram illustrating the post-natal ossification of the hand and wrist, based upon a radiograph of the hand of a girl 12 years old. Diaphyses and carpal bones in light stipple. Epiphyses in dark stipple. Dates of appearance of epiphyses indicated in Arabic numerals. Dates of fusion of diaphyses and epiphyses of the radius and ulna indicated in Roman numerals.

The shaft of the humerus begins to ossify in the sixth or seventh week of fetal life. The humerus has seven epiphyses, one for the head, one each for the greater and lesser tuberosities, and four for the inferior extremity. The epiphysis of the head appears between 6 and 20 months, that of the greater tuberosity between one and three years, and that of the lesser tuberosity between three and five years. These three epiphyses unite in the fourth or fifth year to form one mass which joins with the shaft of the bone between the twentieth and twenty-fifth years. The inferior epiphyses are the capitulum (six months to two years), median epicondylar (five and one-half to nine and one-half years), trochlear (8 to 16 years), and lateral epicondylar (11 to 18 years). The capitular, trochlear, and lateral epicondylar epiphyses first unite to form a single mass and then join the shaft. The median epicondyle joins the shaft separately in the eighteenth year.

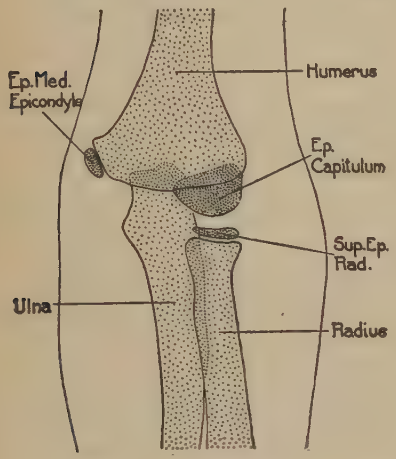

FIG. 99.—A semi-diagrammatic drawing of a radiograph of the elbow-joint of a male child of about nine years.

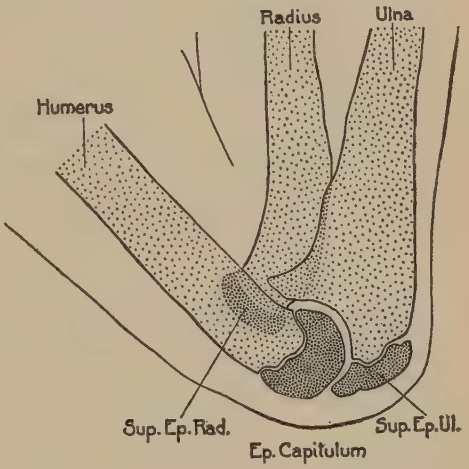

FIG. 100.—A semi-diagrammatic drawing of a radiograph of the elbow-joint of a youth of 14 years.

The center for the shaft of the ulna appears in the seventh week of fetal life. The ulna has two epiphyses, one at the carpal and one at the radial end. The carpal epiphysis appears in the sixth or seventh years in females and in the seventh or eighth years in males; it unites with the shaft between the eighteenth and twentieth years. The humeral epiphysis appears between the eighth and fourteenth years and unites with the shaft in the seventeenth year. Other epiphyses may occur in the styloid and the olecranon processes.

The center for the shaft of the radius also appears in the seventh fetal week. Both the radius and the ulna are said to be longer in proportion to the humerus in the infant than in the adult. The radius has carpal and humeral epiphyses. The former appears in females in the eighth month and in males about the fifteenth month after birth; the latter appears between four and nine years. The humeral epiphysis unites with the shaft between the seventeenth and twentieth years and the carpal between the twenty-first and twenty-fifth years.

The ossification of the carpus is generally entirely post-natal beginning in the early part of the first year and coming to an end shortly before puberty. Investigators differ considerably in their determinations of the order and date of the ossification of the carpal bones. Table 4 is a summary of the findings of more recent students of the subject. In the opinion of the writer the results of Pryor (given in the last column of the table) will be found the most valuable, for work with American children, particularly as he has taken the care to distinguish between the sexes.

Table 4.—Time of Appearance of Centers of Ossification in the Bones of the Corpus as Determined by the Roentgen-ray

	Fuginami[26]	Puyhaubert[17]	Rotch[52]	Pryor[45, 16]	
				Females	Males
Os capitatum (magnum).	2nd mo. (end of 1st to end of 6th mo.)	Last mo. of fetal life to the close of 1st yr.	Very soon after birth	Between 3rd and 6th mos.	Between 4th and 10th mos.
Os hamatum (unciform)	2nd mo. (end of 1st to end of 6th mo.)	1st yr.	Very soon after birth	Between 5th and 10th mos.	Between 6th and 12th mos.
Os triquetrum (cuneiform)	Middle of 3rd yr. (1¼ to 3½ yrs.)	1½ to 4½ yrs.	About the 2nd or 3rd yr.	Between 2nd and 3rd yrs.	At about 3 yrs.
Os lunatum (semilunar).	Middle of 4th yr.	2½ to 6 yrs.	About the 3rd or 4th yr.	Between 3rd and 4th yrs.	At about 4 yrs.
Os naviculare (scaphoid).	Beginning of 6th yr. (beginning of 4th to end of 7th yr.)	5 to 6½ yrs.	About the 5th to 6th yr.	At 4 yrs. or early in 5th yr.	Between 4th and 5th yrs.
Os multangulum minus (trapezoid).	Beginning of 6th yr.	4½ to 6½ yrs.	About the 6th to 8th yr.	Between 4th and 5th yrs.	Between 5th and 6th yrs.
Os multangulum majus (trapezium)	Beginning of 6th yr.	3½ to 6 yrs.	About the 5th yr.	Between 4th and 5th yrs.	Between 5th and 6th yrs.
Os pisiforme.........	Beginning of 12th yr.	10 to 14 yrs.	About the 12th yr.	Between 9th and 10th yrs.	Between 12th and 13th yrs.

There appears to be a large amount of variation in both the time and order of the ossification of the carpal bones even in normal children. Pryor [45] summarizes his results, based on the study of 554 children, as follows:

(*a*) "The bones of the female ossify in advance of the male. This is measured at first by days, then months, then years.

(*b*) "The bones of the first child, as a rule, ossify sooner than those of subsequent children.

(*c*) "Regardless of the variations (normal) the ossification is bilaterally symmetrical.

(*d*) "Variation in the ossification of bones is a heritable trait."

The degree of variation in the order of the carpal bones as well as in the carpal complex at different ages is shown in Table which is based upon a numerical summary of Pryor's cases. Most investigators other than Pryor have found that the ossification of the multangulum majus (trapezium) precedes that of the multangulum minus (trapezoid).

The variation in the time of ossification of the carpal bones is illustrated in the following table by Brice based upon the data of Puyhaubert.[47]

All the carpal bones commonly ossify from a single center. However cases of two centers have been reported for the naviculare (scaphoid), lunatum (semilunar), triquetrum (cuneiform), hamatum (unciform); multangulum majus (trapezium) and pisiforme.

The centers for the diaphyses of the metacarpals and phalanges appear in the ninth week of fetal life. Ordinarily epiphyses are formed only at the distal ends of the metacarpals although proximal epiphyses for the first and second metacarpals are present occasionally. The epiphyses of the phalanges are all proximal. The epiphyses of the long bones of the hand are formed between the latter part of the first and the latter part of the third year. The epiphyses of the metacarpals unite with their shafts between fifteen and twenty years. Those of the phalanges fuse with their shafts between the eighteenth and twentieth years.

The ossification of the sesamoid bones of the hand generally begins at puberty.

Inferior extremity (Figs. 96, 97, 101, 102, 103.)—The femur has four epiphyses; one for the inferior extremity, one for the head, one for the greater trochanter, and one for the lesser trochanter. The inferior epiphysis is generally present at birth; the epiphysis for the head appears between six months and two years after birth; that of the trochanter major between three and one-half and six years; and that for the trochanter minor between 7 and 11 years. The epiphyses unite with the shaft in the reverse of the order of their appearance; the lesser trochanter in the seventeenth year, the greater trochanter in the eighteenth, the head in the eighteenth or nineteenth, the inferior from the eighteenth to twenty-second year.

The shaft of the femur at birth is quite straight, whereas in the adult it is always bent in a gentle arch with its concavity directed backward. This bend is acquired during childhood with the assumption of the erect posture. At birth and for some time thereafter the neck of the femur is very short and forms a much more acute angle with the shaft than in the adult. During the latter part of fetal life the femur undergoes a high degree of torsion so that in the newborn the angle between the axis of the head and neck, and the transverse axis of

Table 5.—The Order of Ossification of Bones of the Carpus in Percentages of Frequency (Based upon the Data of Pryor.[47] To Find the Order Frequency of a Given Bone Read the Left Hand Figures from above Downward. To Find the Frequency of all Bones in a Given Order Read the Figures in Parentheses from Left to Right. Percentages are Calculated to the Nearest Whole Numbers)

Order	Os capitatum (magnum)	Os hamatum (unciform)	Os triquetrum (cuneiform)	Os lunatum (semilunar)	Os naviculare (scaphoid)	Os multangulum minus (trapezoid)	Os multangulum majus (trapezium)	Os pisiforme (pisiform)
First	98 (98)	2 (2)						
Second	2 (2)	98 (98)						
Third	......	......	96 (96)	4 (4)				
Fourth	......	......	4 (5)	86 (86)	2 (1)	6 (4)	6 (3)	
Fifth	......	......	......	4 (5)	62 (52)	29 (24)	25 (19)	
Sixth	......	......	......	1 (2)	21 (23)	48 (50)	26 (26)	
Seventh	......	......	......	3 (6)	15 (20)	17 (22)	43 (52)	
Eighth	......	......	......	......	......	......	......	100

TABLE 6.—OSSIFICATION OF CARPUS (Tabulated by Brice, Quain's Anatomy, 11 ed., from the Data of Puyhaubert[47])

Bones	Percentage of cases in which ossification centers are present at							
	Birth	1st yr.	2nd yr.	3rd yr.	4th yr.	5th yr.	6th yr.	7th yr.
Os capitatum (magnum)	20	100	100	100	100	100	100	100
Os hamatum (unciform)	20	100	100	100	100	100	100	100
Os triquetrum (cuneiform)	..	...	20	50	80	100	100	100
Os lunatum (semilunar)	..	...	...	20	30	36	80	100
Os multangulum majus (trapezium)	..	...	...	...	8	1	70	100
Os multangulum minus (trapezoid)	..	...	...	...	...	1	70	100
Os naviculare (scaphoid)	..	...	...	...	...	1	60	100

the body of the bone is 36.5° in the right femur and 32.4° in the left. In the adult the angle is from 8 to 10°. It seems probable that congenital dislocations of the hip are the result of this torsion and that their greater frequency on the right side can be explained on the basis of the preceding figures. The degree of torsion in the femur of females is slightly greater than that of males; and this, together with the differences in the acetabula already mentioned, probably accounts for the higher percentage of congenital dislocations in girls than in boys.

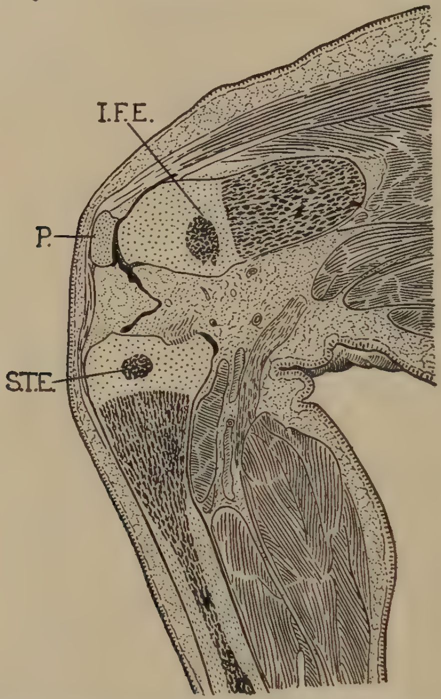

Fig. 101.—Median section of the left knee of the newborn male child 54 cm. long. I.F.E., inferior femoral epiphysis; P., patella; S.T.E., superior tibial epiphysis. Natural size.

The tibia has two constant epiphyses for the superior and inferior extremities, and generally one for the tubercle as well. The superior epiphysis is generally present at the time of birth and joins the shaft between the seventeenth and twenty-fourth years. The inferior epiphysis appears between the sixth and fifteenth post-natal months and fuses with the shaft between 16 and 19 years. The tuberosity of the tibia is commonly formed in part from a downgrowth from the superior tibial epiphysis, and in part from a small separate center lying just below this process. A second center may be present. The time of formation of the separate center is extremely variable. Its presence in the first year has been reported but it commonly appears between the seventh and fifteenth years. It usually joins with the process of the superior epiphysis between the twelfth and fifteenth years. Fusion with the shaft of the tibia takes place along with that of the superior epiphysis between the seventeenth and twenty-fourth years (Kirchner).[33]

Because of the importance of the inferior femoral and superior tibial epiphyses in determining the maturity of the newborn infant I include a summary of the recent work of Pozier[44] on this subject. This author examined the knees of 166 newborn children by means of the Roentgen ray. His conclusions were; (1) the same number of centers are found in the right and left members of any newborn; (2) if a single center is present it is always the inferior femoral epiphysis; (3) there is no direct relation between the development of the ossification centers at the knee and body-weight; (4) the inferior femoral epiphysis generally appears at the beginning of the last fetal month and the superior tibial epiphysis in the week preceding birth; (5) all children with two centers, weighing 2,700 gm. or more and measuring 47 cm. or more in length are full-term; (6) children with two ossification centers weighing 2,600 gm. or less and measuring 44 cm. or more are at term or nearly so; (7) all children with one center weighing 2,800 gm. and measuring 44 cm. or more are full-term or nearly so; (8) all children with two centers are at least eight and one-half months; (9) all infants weighing less than 2,500 gm. and without ossification centers are less than full-term. The following is a tabular summary of Pozier's data. A further discussion of this subject is given by Adair and Scommon (Am. Jour. Obstet. and Gynecol., II (1921).

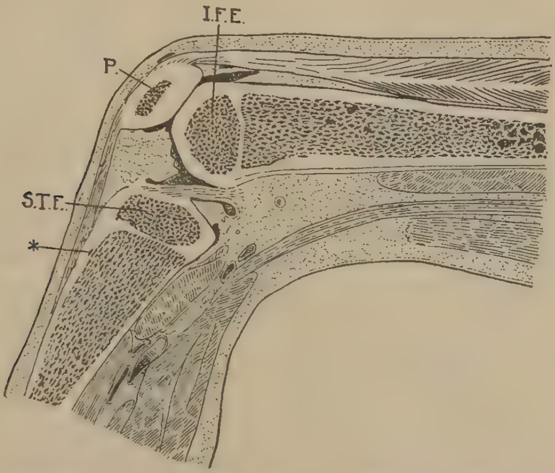

FIG. 102.—Median section of the knee of a female child nine years of age. I.F.E., inferior femoral epiphysis; P., patella; S.T.E., superior tibial epiphysis. *Accessory epiphysis for tubercle of the tibia. One-half natural size.

TABLE 7.—THE DEVELOPMENT OF THE OSSIFICATION CENTERS OF THE KNEE (AFTER POZIER[44])

Age in weeks calculated from last menstruation	Number of cases	Percentage of cases in which:		
		No center is present	One center only is present	Two centers are present
33 to 35	7	57	43	0
35 to 37	12	17	42	42
37 to 39	15	27	33	40
40th	34	3	32	59
40 to 42	54	6	30	65
42 and over	19	0	16	84
Total	141			

The fibula has an inferior and a superior epiphysis. An inferior epiphysis appears between 15 months and 2½ years and a superior epiphysis between three and one-half and six and one-half years. The superior epiphysis joins the shaft between 20 and 22 years and the inferior between 22 and 24.

The ossification center of the patella appears between three and six years.

Bones of the Foot.—Although the development of the tarsus has not been studied in the same detail as has that of the carpus there is a considerable amount of data upon the subject. Unlike the carpal bones, which are commonly all cartilaginous at birth, two bones of the tarsus, the calcaneus and the talus (astragalus) always possess ossification centers in the full-term newborn; and a third bone, the cuboid, is ossified in over one-half of the cases. All observers are agreed as to the customary order of the tarsal bones, which is as follows: (1) calcaneus, (2) talus (astragalus), (3) cuboid, (4) third or external cuneiform, (5) first or internal cuneiform, (6) second or middle cuneiform, and (7) navicular (scaphoid). The time of appearance of these centers of ossification is indicated in the following table which is the summary of the more important studies on the subject.

Several of the tarsal bones arise from more than one ossification center. The calcaneus often has a periosteal center which arises a little earlier than the main center and generally soon fuses with it. The talus, cuboid and first (internal) cuneiform may also form from several centers which fuse shortly after their appearance. The navicular commonly has a secondary smaller lateral center which appears shortly after the main one and fuses with it before puberty.

The calcaneus is the only tarsal bone having an epiphysis. This is formed, sometimes from several centers, between the sixth and tenth years and generally joins with the main mass of the bone shortly after

TABLE 8.—TIME OF APPEARANCE OF CENTERS OF OSSIFICATION IN THE BONES OF THE TARSUS AS DETERMINED BY THE ROENTGEN RAY

	Bade[17]	Hasselwander[28]	Freymond[24]	Rotch[52]	Puyhaubert[47]
Calcaneus (main centers)	End of 6th fetal mo. or beginning of 7th.	Periosteal center 4½–5 fetal mo. Main center 6 fetal mos.	....	6th fetal mo.	
Calcaneus (epiphysis)	....	8 yrs.	....	9th yr.	6 to 9 yrs.
Talus (astragalus)	End of 7th or beginning of 8th fetal mo.	7th fetal mo.	....	7th fetal mo.	
Cuboideum	After birth	Last fetal mo.	1st half of 1st yr.	9th fetal mo.	Last fetal to 6th post-natal mo.
Naviculare	....	3½ yrs.	2nd to 3rd yr.	4th yr.	External center 2½ to 3½ yrs. Internal center 4 to 5½ yrs.
Cuneiform III	Between birth and 6 mos.	5 to 6 mos.	End of 1st yr.	1st yr.	6 to 18 mos.
Cuneiform I	16th mo.	3 yrs.	End of 2nd yr.	3rd yr.	1½ to 2½ yrs.
Cuneiform II	2 to 2½ yrs.	3 yrs.	End of 2nd or beginning of 3rd yr.	4th yr.	2½ to 3½ yrs.

puberty. Occasionally fusion takes place immediately after the formation of the epiphyseal center.

As a rule the tarsal bones ossify earlier in girls than in boys.

The shafts of the metatarsals ossify about the end of the second fetal month. The epiphysis of the first metatarsal is proximal to the shaft but all of the others are distal. Occasionally the first metatarsal may have a distal epiphysis as well, and a separate center may be formed for the tuberosity of the first metatarsal. The epiphyses appear in the latter part of the third year. Ossification begins in the medial metatarsal epiphysis and proceeds laterally. The epiphyses unite with the shafts between the fourteenth and nineteenth years in females and between the seventeenth and twenty-first years in males.

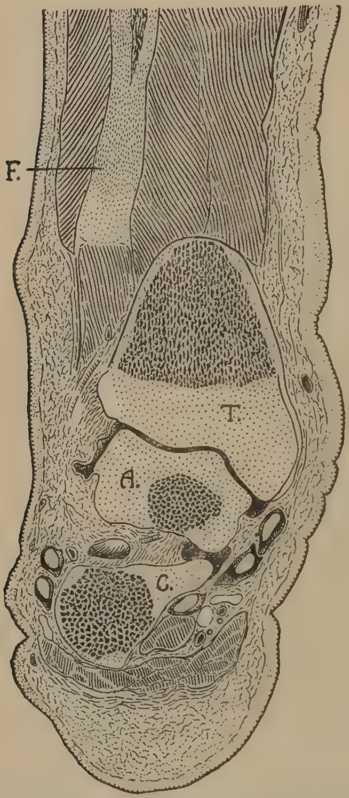

Fig. 103.—Vertical section of the ankle of the newborn male child, 54 cm. in length. A., astragulus (talus); C., calcaneus; F., fibia; T., tibia.

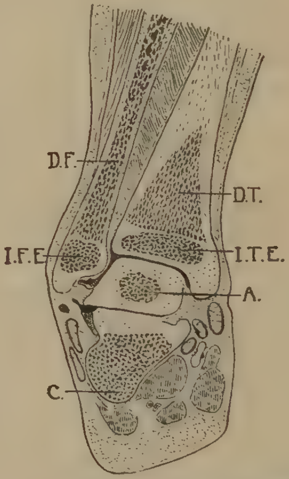

Fig. 104.—Vertical section of the ankle of a girl nine years old. A., astragulus (talus); C., calcaneus; D.F., diaphysis of fibula; D.T., diaphysis of tibia; I.F.E., inferior epiphysis of fibula; I.T.E., inferior epiphysis of tibia.

The shafts of the phalanges are ossified in the third fetal month. The epiphyses, which are proximal in position, are formed in the third and fourth years. They appear first in the proximal row and last in the distal row of phalanges. The period of union of the epiphyses with their shafts extends from the twelfth to the twenty-first year. The epiphyses of the distal row of phalanges are the first to unite with their shafts and the proximal row are the last. The process takes place earlier in females than in males.

The sesamoid bones of the great toe appear in the eighth year in females and in the eleventh year in males.

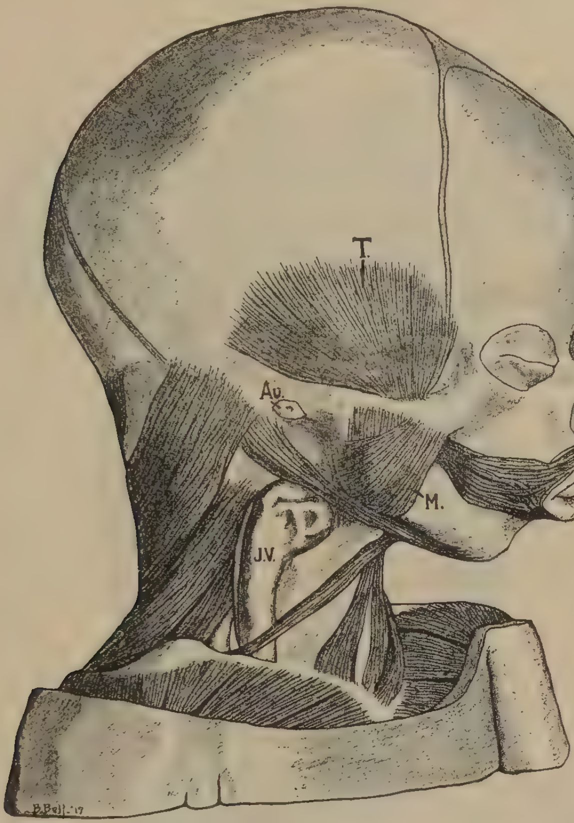

FIG. 105.—Lateral view of the musculature of the head and neck of a full-term newborn child. (Drawn from a dissection and cast by Dr. J. C. McKinley.) Au., auricle; J.V., jugular vein; M., masseter muscle; T., temporal muscle.

Skeleton of the Foot as a Whole.—In the early part of fetal life the foot is strongly inverted. About the seventh fetal month a process of gradual eversion begins but at birth and for some time thereafter some inversion is still noticeable. Eversion is brought about by profound changes in the shape of the calcaneus and talus, and by the rapid growth of the bones forming the medial border of the foot. At birth the foot also has a greater degree of dorsoflection than in later life, due to the greater relative area of the trochlea of the talus. Ventral flexion, however, is limited by the shortness of the dorsal extensor muscles.

If an impression be made on smoked paper or glass of an infant's foot, almost the entire plantar area is outlined and a picture is secured quite similar to that seen in cases of flat foot in the adult. Definite transverse and longitudinal plantar arches are present, however, even at the time of birth; and the latter is higher relatively than in the adult.

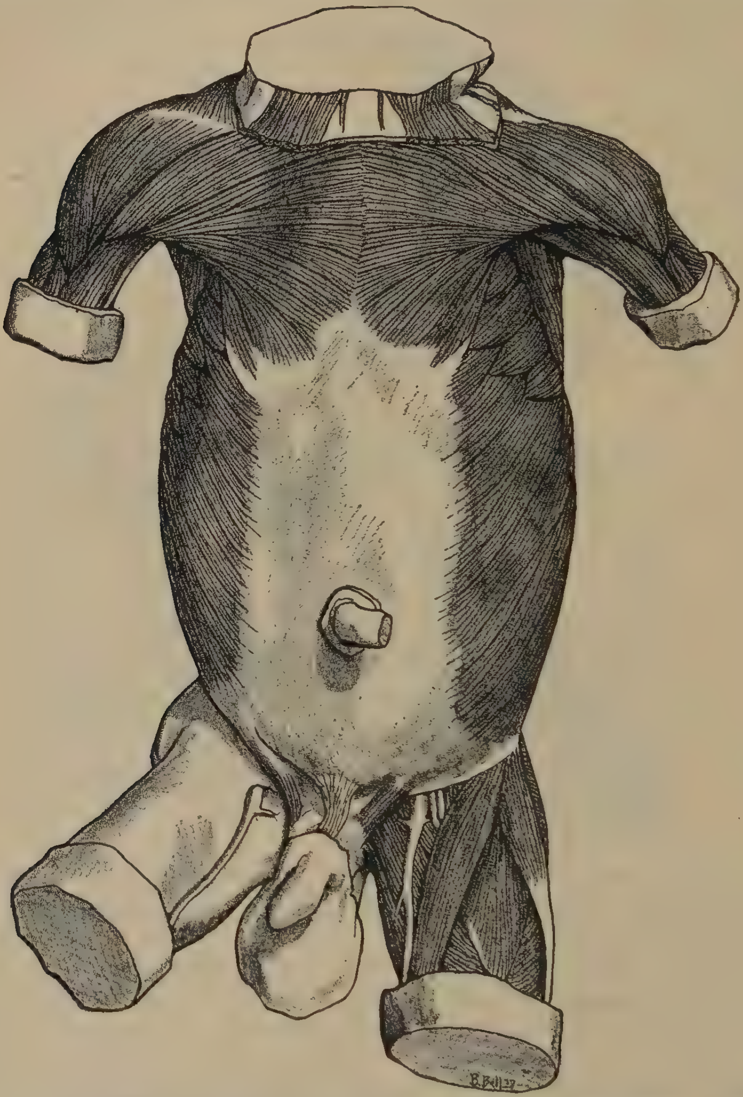

FIG. 106.—Superficial musculature of the trunk of a newborn child. (Drawn from a dissection and cast by Dr. J. C. McKinley.)

The arches are concealed in the impressions by the thick pad of plantar fat which acts as a support until the posterior leg muscles and plantar fascia take over this function. Dane,[20] who measured the longitudinal plantar arch in a number of infants, found both an absolute and relative decrease in the height of the arch during the second year of life, in the period when the child first begins to bear its weight upon its feet.

THE MUSCULATURE (Figs. 105, 106, 111)

We know comparatively little regarding the post-natal development of the muscular system. According to the observations of Theile[65] and others, the muscles form about one-fourth of the entire body weight at birth. Apparently the muscles do not grow as fast as the remainder of the body during infancy but in later childhood they increase so rapidly that at puberty, as in later life, they form 40 to 45 per cent. of the total body weight. The absolute gain in the weight of the musculature between birth and maturity varies greatly in different individuals but generally it is nearly forty-fold or about twice that of the body as a whole.

In the newborn the muscles of the head and trunk form a little over 40 per cent. of the total weight of the musculature while in maturity they form from 25 to 30 per cent. During childhood the muscles of the inferior extremities increase from a little over 40 per cent. to about 55 per cent. of the total weight of the musculature. The muscles for the superior extremities form from 18 to 20 per cent. of the entire musculature throughout post-natal life.

The growth of skeletal muscles during post-natal life apparently is due almost entirely to the increase in volume of the individual fibers and not to an increase in their number. MacCallum[60] estimates that the muscle fibers of the sartorius increase about 10 per cent. in number and about 800 per cent. in area in cross-section between birth and maturity.

The literature contains a few scattered observations regarding the topography of certain of the muscles during childhood but the subject as a whole is practically untouched. Through the kindness of Dr. J. C. McKinley I am able to reproduce here two figures of the musculature of the newborn child which are a part of his forthcoming monograph on the subject (Figs. 105, 106).

The submuscular and subfascial bursæ and the mucous sheaths of the tendons of the various muscles are practically all fully developed at the time of birth. The subcutaneous bursæ are more variable and may or may not be completely developed in the newborn. When absent at birth they develop in the course of the first few years. For details regarding their condition in the newborn and their later development the reader is referred to the papers of Heincke[59] and Whittaker.[63]

THE DIGESTIVE SYSTEM

THE MOUTH AND TONGUE (Figs. 107, 108)

The lips of the newborn and young infant show two anatomical modifications fitting them for the act of sucking. The red part of the mucosa is differentiated into two zones—an external smooth one, the pars glabra, and an internal one which is studded with long pointed papillæ and is known as the pars villosa. The papillæ not only cover the pars villosa of the lips but extend backward in an irregular band along each cheek nearly to its posterior margin. In the mid line of the upper lip in the pars villosa is a distinct elevation—the superior labial tubercle. Both the tubercle and the papillæ of the pars villosa ordinarily disappear in the first few months but either may persist to some degree in adult life.

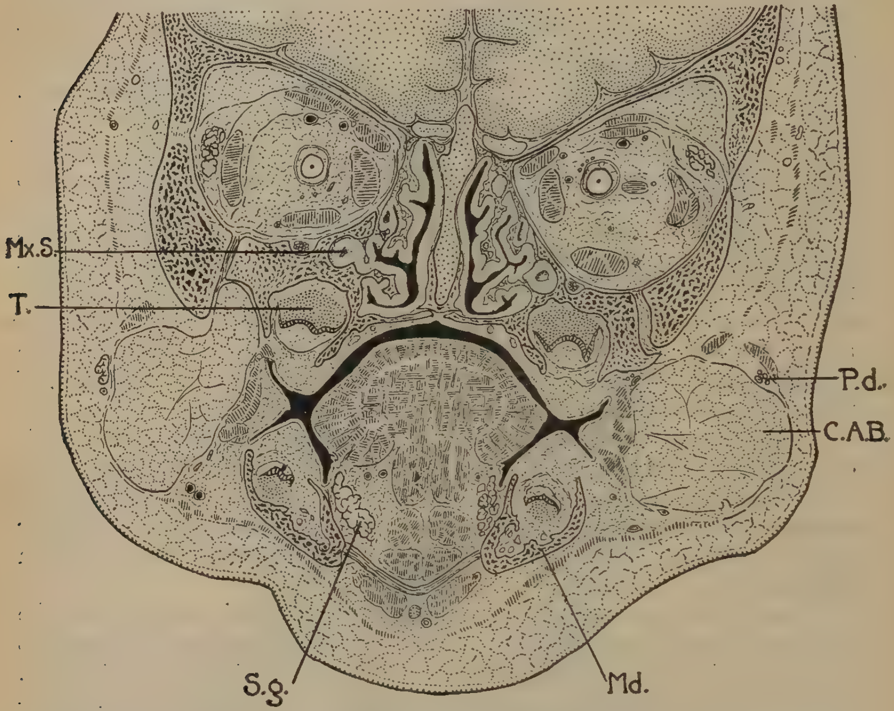

Fig. 107.—Frontal section of the face of a full-term newborn child. C.A.B., corpus adiposum buccæ (sucking pad); Md., mandible; Mx.S., maxillary sinus; P.d., parotid duct; S.g., sublingual gland; T., germ of molar tooth. Natural size.

The oral cavity of the infant is only a potential one for when the mouth is tightly closed the tongue comes in contact with the gums laterally and with the roof of the mouth above. When the mouth assumes the position for sucking there are formed three cleft-like spaces through which fluids can be carried to the pharyngeal cavity. A median cavity, the Cavum suctorium of Hasse,[92] lies between the dorsum of the tongue below and the hard palate above, and opens into the cavity of the isthmus of the fauces through a narrow aperture on either side of the soft palate. The two lateral cavities are arcuate clefts bounding the lateral and medial surfaces of the gums respectively. They communicate freely since the upper and lower gums are not completely in contact in the newborn child or the suckling. Fluids from these lateral spaces enter the cavity of the isthmus through a cleft between the lateral margin of the tongue and the anterior pillar of the fauces (glossopalatine arch). In the suckling the cavity of the isthmus is closed off from the oropharynx except for two small lateral openings which are bounded by the epiglottis, the soft palate, and the posterior pillars of the fauces (arcus). These two apertures are in front of the opening of the larynx and are partly separated from it by the posterior palatine arches so that fluids may pass into the pharynx and esophagus without entering the cavity of the larynx.

The hard palate of the young child is low, broad and short. Generally it is corrugated by a series of five or six irregular transverse folds. These structures are very much more prominent in the fetus than in the child and may be either entirely obliterated or broken up into mound-like elevations before maturity. Possibly they assist in holding the nipple during the sucking act. A small conical projection, the incisive papilla, occurs at the middle of the anterior margin of the palate. Along the median line of the palate in the newborn there occur a series of epithelial masses or pearls, which often form whitish rounded elevations on the surface of the mucosa. According to Epstein,[83] these are epithelial debris which are left behind in the union of the halves of the hard palate.

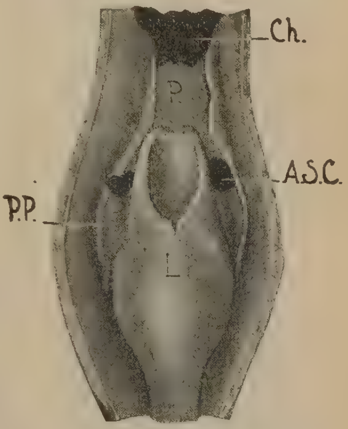

Fig. 108.—Posterior view of the anterior wall of the pharynx of a newborn child. A.S.C., posterior aperture of salivary space (apertura salivariæ commune); Ch., posterior choanæ; L., larynx; P., soft palate; P.P., posterior palatine pillars. (After Hasse.[92])

The tongue of the infant is relatively short and broad. The sulcus terminalis which indicates the division between the oral and pharyngeal portions of the organ is well marked and the foramen cæcum is generally a large distinct pit. All the types of lingual papillæ recognized in the adult are present before birth. Taste buds are present on the vallate, foliate, and fungiform papillæ of the newborn and in the epithelium of the foramen cæcum. They are said to increase considerably in number during the first year of life. The lymphoid follicles of the lingual tonsil are formed in the ninth or tenth fetal month. These are relatively more numerous in the child than in the adult.

The Sucking Pad (Figs. 107, 111)

In either cheek of the newborn child there is a sharply circumscribed mass of adipose tissue known as the sucking pad or bolus of Bichat (corpus adiposum buccæ). The main mass of this fatty body lies in the space between the buccinator and masseter muscles and is covered externally by the facial muscles and fascia. From this more superficial portion a process extends backward and inward to join the temporal fat-mass. The superficial portion is from 1.5 to 2 cm. in diameter. The parotid duct comes in close relation with the sucking pad and may pass either directly above it or through a deep groove on its external surface. The sucking pad contains fats of a higher melting point than those of the general superficial adipose tissue and is little diminished even in cases of extreme emaciation. Its finer structure, in the new-born, is practically identical with that of the general superficial fat.

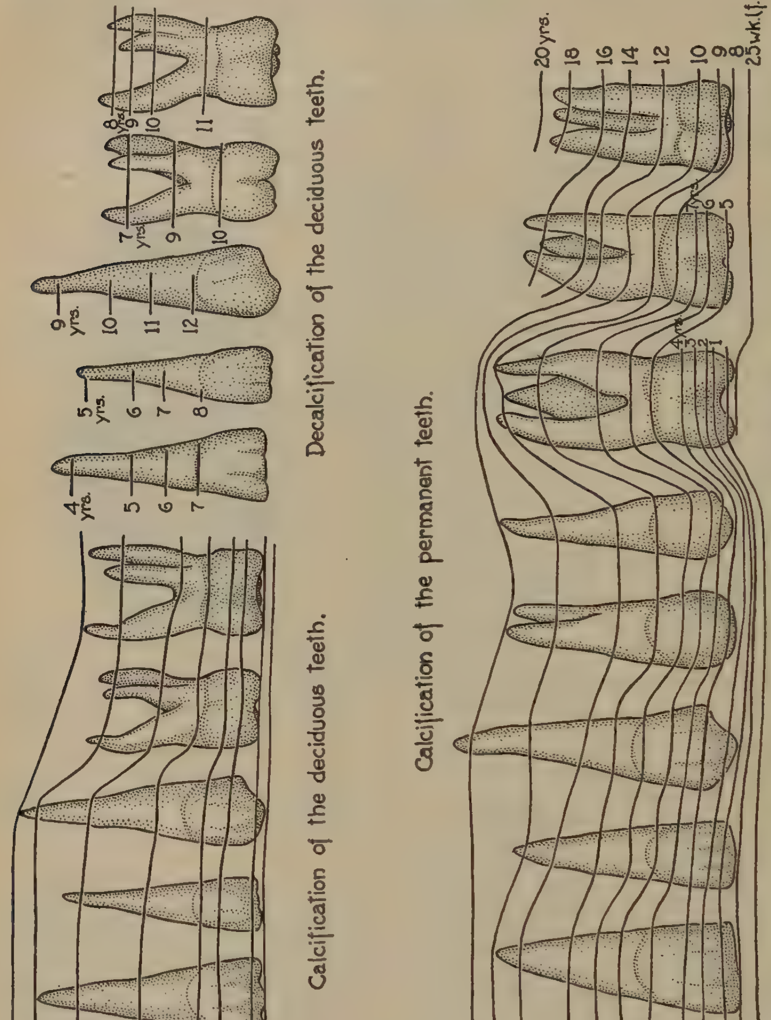

FIG. 109.—Diagram illustrating the calcification of the permanent and deciduous teeth, and the decalcification of the latter. (After Poirier and Charpy, Traite Anat. Humaine, 2m. Ed.)

The body is surrounded by a special capsule of fibrous connective tissue. Its function is supposed to be the distribution of atmospheric pressure and preventing the drawing in of the cheek and buccinator muscle, between the gums during the sucking act (Ballantyne[1]). In most cases, the sucking pad persists throughout childhood and even into adult life.

THE TEETH (Figs. 92, 93, 107, 109, 110)

All of the deciduous teeth and the germs of the upper and lower permanent first molars are partially calcified at the time of birth. The germs of the remaining permanent teeth, with the exception of the third molars, are also present at this time although the process of calcification has not begun in them.

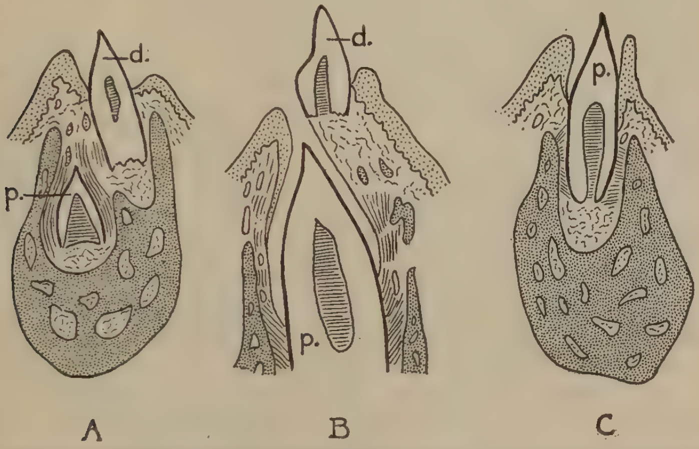

FIG. 110.—Semi-diagrammatic sections illustrating the shedding of the deciduous and eruption of the permanent teeth. A, child five and one-half years old, section through median inferior incisor. B, child six and one-half years old, section through lateral inferior incisor. C, child six and one-half years old, section through median inferior incisor. d., deciduous tooth; p., permanent tooth. (After Albarran.[64])

The germs of the deciduous teeth and of certain of the permanent ones are inclosed in definite connective tissue sacs (dental sacs) which are attached by their apices to the connective tissue of the oral mucous membrane and at their sides and bases to the periosteum of the mandible or maxillæ. These dental sacs are lodged in incomplete bony alveoli, which occupy the greater part of the mandible and of the bases of the maxillæ. The alveoli which contain the deciduous teeth extend from the bases of the rami of the mandibles to the symphysis in the lower jaw and from the posterior margins to the future nasal spines of the maxillæ. The germs of the anterior permanent teeth, from median incisors to the first premolars inclusive, lie medial to the deciduous teeth, while the germs of the first and second molars are placed posterior to them.

The chronology of the eruption of both the deciduous and permanent teeth is subject to great individual and probably some racial variation. Usually the eruption of the former begins with the lower central incisors in the early part of the second half year and ends with the second molars in the latter part of the second year. As a rule, the eruption of the deciduous teeth takes place in a series of periods of activity which are separated by periods of quiescence which grow progressively longer; but there is considerable variation in this process. The details of the calcification and eruption of the deciduous teeth are shown in Table 9 and Fig. 109.

Following the eruption of the second deciduous molars is a period in which there are no external changes in the dentation. During this time, however, all of the permanent teeth with the exception of the first and third molars commence to calcify and towards the end of it the decalcification of the deciduous incisors begins.

The shedding of the deciduous teeth, which is even more irregular than their eruption, starts with the incisors, usually in the seventh year, and ends with the premolars or second molars in the twelfth year.

The first of the permanent teeth to erupt are the first molars. These teeth undergo precocious development from the beginning, being the only ones of the permanent series which begin to calcify in fetal life. The usual time of eruption is in the sixth or seventh year. The permanent dentation, with the exception of the wisdom teeth or third molars, is usually complete by 14 or 15 years. The wisdom teeth may make their appearance at almost any time from this period to the close of the third decade, although generally they are erupted before 20. In general, the teeth of the permanent dentation appear from one to six months earlier in girls than in boys.

A few words may be added concerning the nature of these processes whose chronology has just been outlined.

The *calcification* of teeth begins at their crowns and proceeds towards the roots. Simple teeth, such as the incisors and canines, have single centers of calcification. Teeth with more than one cusp have separate calcification centers for each cusp. These centers fuse in their later development. In general, there are two main periods of calcification, one in the fourth and fifth fetal months, when the centers of the deciduous teeth are established; and a second extending through the first five years of post-natal life, when the centers of most of the permanent teeth are laid down. The exceptions to this scheme are the permanent first molars, which commence to calcify in the last fetal month; and the third molars or wisdom teeth, in which the process is delayed until the eight or ninth year. While clacification is always well advanced at the time of eruption it is not completed in the case of the deciduous teeth until some time thereafter. In the permanent teeth it is nearly or quite finished at the time of eruption.

The *decalcification* of the deciduous teeth begins at or near the apices of the roots and proceeds towards the crowns. When the tooth is shed practically all of the fang has been destroyed. This is said to be brought about mainly through the action of osteoclasts. Prior to the shedding of the tooth the upper part of the temporary alveolus is absorbed and the peridental membrane becomes loosened. A diagram of the process is shown in Fig. 110.

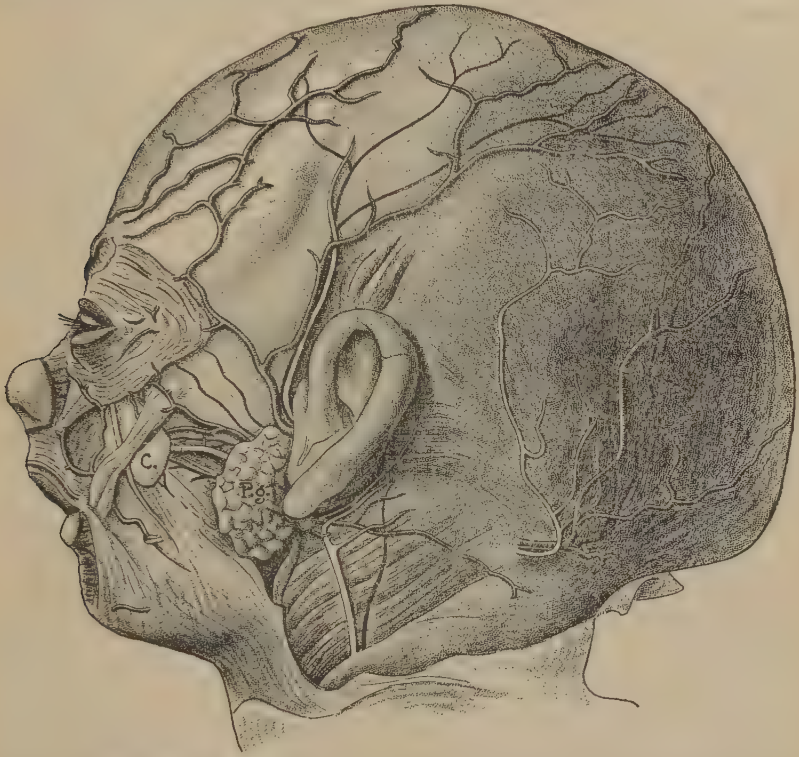

FIG. 111.—Dissection of the head of a child one month old. P.g., parotid gland; C., corpus adiposum buccæ (sucking pad).

In the process of *eruption*, the crown of the growing tooth is pressed against the oral margin of the alveolus which encloses it, and the aperture at this place is enlarged through the absorption of its margins until an opening is formed which is large enough to allow the passage of the crown. At the same time the mucoperiosteum covering this region becomes reduced in thickness and of softer texture. The crown pierces this tissue carrying a thin covering derived from the inner part of the enamel organ known as the dental cuticle or Nasmyths membrane. The remains of dental sac in which the tooth was enclosed fuses with and becomes part of the periosteum of the alveolus which is rapidly rebuilt around the neck of the tooth.

The details of the development of the teeth will be found presented in full in the texts of Noyes, and Broomell and Fischelis, and the

TABLE 9.—SUMMARY OF THE DEVELOPMENT OF THE DECIDUOUS AND PERMANENT TEETH
(Based on the observations of Broomell and Fischelis, and Röse)

Deciduous teeth

Upper and lower teeth	Calcification begins	Calcification completed	Usual time of eruption	Decalcification begins	Shedding begins
Medial incisors	4th fetal mo.	16th to 18th mo.	6th to 8th mo.	4th yr.	7th yr.
Lateral incisors	4th fetal mo.	10th to 16th mo.	7th to 9th mo.	5th yr.	8th yr.
Canines	5th fetal mo.	2 yrs.	17th to 18th mo.	9th yr.	10th yr.
First molars	5th fetal mo.	18th to 20th mo.	14th to 15th mo.	6th to 7th yr.	10th yr.
Second molars	5th fetal mo.	20th to 22nd mo.	18th to 24th mo.	7th to 8th yr.	11th to 12th yr.

Permanent teeth

Upper teeth	Calcification begins	Calcification completed	Average time of eruption		Usual period of eruption
			Males	Females	
Medial incisors	1st yr.	10th to 11th yr.	7 yrs. 8 mos.	7 yrs. 5 mos.	7th to 8th yr.
Lateral incisors	1st yr.	10th to 11th yr.	8 yrs. 11 mos.	8 yrs. 6 mos.	7th to 8th yr.
Canines	3rd yr.	12th to 13th yr.	12 yrs. 2 mos.	11 yrs. 7 mos.	12th to 13th yr.
First premolars	4th yr.	11th to 12th yr.	10 yrs. 5 mos.	10 yrs. 1 mo.	8th to 11th yr.
Second premolars	5th yr.	11th to 12th yr.	11 yrs. 4 mos.	11 yrs. 1 mo.	11th to 12th yr.
First molars	10th fetal mo.	9th to 10th yr.	6 yrs. 7 mos.	6 yrs. 6 mos.	6th to 7th yr.
Second molars	5th yr.	16th to 18th yr.	12 yrs. 9 mos.	12 yrs. 5 mos.	12th to 14th yr.
Third molars	9th yr.	18th to 20th yr.	....	....	17th to 20th yr.
Lower teeth					
Medial incisors	1 st yr.	10th yr.	6 yrs. 10 mos.	6 yrs. 7 mos.	7th to 8th yr.
Lateral incisors	1st yr.	10th to 11th yr.	7 yrs. 11 mos.	7 yrs. 7 mos.	8th to 9th yr.
Canines	3rd yr.	12th to 13th yr.	11 yrs. 2 mos.	10 yrs. 3 mos.	12th to 13th yr.
First premolars	4th yr.	11th to 12th yr.	11 yrs. 3 mos.	10 yrs. 8 mos.	10th to 11th yr.
Second premolars	4th to 5th yr.	11th to 12th yr.	12 yrs. 0 mos.	11 yrs. 7 mos.	11th to 12th yr.
First molars	10th fetal mo.	9th to 10th yr.	6 yrs. 5 mos.	6 yrs. 3 mos.	6th to 7th yr.
Second molars	5th yr.	16th to 17th yr.	12 yrs. 3 mos.	11 yrs. 9 mos.	12th to 16th yr.
Third molars	8th to 9th yr.	18th yr.	....	....	16th to 20th yr.

relations of the teeth in childhood are well illustrated in the atlases of Symington and Rankin[127] and Witzel.[139] Among the more extensive statistical studies upon the chronology of the eruption of the teeth are those of Röse[120] and James and Pitts.[97] The development and growth of the dental arches has been considered in connection with the post-natal history of the jaws.

THE SALIVARY GLANDS (Figs. 107, 111)

The relative weight of the salivary glands as a whole is approximately the same in the newborn and the adult. The parotid is however a little lighter proportionally while the submaxillary and the sublingual are a little heavier. The absolute weight of the parotid in the newborn averages 1.8 gm., that of the submaxillary 0.84 gm., and that of the sublingual 0.42 gm. All of these glands increase approximately three times in weight during the first six months, and five times during the first two years.

The topography of the submaxillary and sublingual glands is practically the same in the infant as in the adult and needs no special description.

The parotid gland in the newborn and young infant is rounder than in later life. It lies wedged in the hollow between the masseter muscle and the ear. During early childhood the parenchyma of the gland gradually grows over the surface of the masseter muscle along the course of the parotid duct until the final form of the adult gland is acquired.

The finer structure of the salivary glands in infancy is characterized by the relatively large amount of interstitial connective tissue and the limited amount of parenchyma. The lobules are separated by broad bands of delicate connective tissue in which the cellular elements are prominent. Within the lobules the ducts form a much larger proportion of the tissue than in later life. The basal granular rods of the secretory ducts are said to be absent during the first year. The end pieces are extremely variable in size as are the cells that form them. In the margins of the alveoli which lie at the periphery of the lobule there are found many small and undifferentiated cells evidently in the process of active growth. Mucous cells are found scattered among the smaller and more primitive ones. Small and faintly staining granules, which are probably secretory, are present in the end-pieces of the parotid and submaxillary gland at birth. According to Berger (quoted by Gundobin[7]) the salivary glands have acquired all the histological characters of the adult by the end of the second year.

THE PHARYNX (Figs. 108, 114, 133, 135, 139)

The pharynx in the newborn is about 4 cm. in length, being approximately one-third as long as in the adult. It is in contact superiorly with the basal portions of the sphenoid and occipital bones, and with the synchondrosis which joins them. The pharynx extends inferiorly to the level of the fifth or sixth cervical vertebra behind and the cricoid cartilage in front.

The main differences in form of the pharynx in the infant and the adult are found in the upper part of the structure. In the newborn, the nasal pharynx is a narrow tube about 20 mm. in length which runs anteroposteriorly in direct line with the nasal fossæ. Its transverse diameter is two or three times greater than the vertical. The nasal pharynx curves gently downward at its posterior end to join the oral pharynx, without any sharp line of demarkation.

During the first five years of life the form of the pharynx is greatly changed through the increase of its vertical diameter. In this period, according to the data of Escat,[84] the transverse diameter increases over one-half (from 12 to 15 mm. to 21 mm.), the anteroposterior diameter remains practical unchanged (at 20 mm.), and the vertical diameter increases nearly three fold (from 5 to 7 to 15 mm.). From 5 to 14 years all of the diameters of the pharynx increase but the vertical still grows the fastest. After puberty the growth of the nasopharynx takes place at about an equal rate in all directions. At birth and for some time thereafter no sharp line can be drawn between the posterior wall and the roof of the pharynx; the two form together a single curving surface. By five years, however, the posterior wall and roof meet at an oblique angle, and by puberty they join nearly at right angles, as in the adult.

The ostium of the Eustachian (auditory) tube at birth and during the first year lies at the level of the floor of the nasal cavity at the line of junction of the hard and soft palates. At this time the ostium of the tube is very small and the fold surrounding it (the torus tubarius) is practically absent because of the weak development of the tubal cartilage. After the first year the ostium is shifted upward and backward and by the end of the fifth or sixth year it generally lies posterior to the inferior nasal concha as in the adult. There is, however, considerable individual variation in the chronology of this process. The pharyngeal recess, or fossa of Rosenmüller, is often hardly distinguishable in the newborn. It is rendered prominent by the posterior shifting of the ostium and the coincident development of the torus tubarius.

THE PHARYNGEAL TONSIL (Figs. 114, 133, 135)

The posterior part of the roof of the pharynx contains a small median pit, the bursa pharyngea or fossa of Luschka, and from this pit a series of folds radiate forward and laterally. The pharyngeal tonsil is formed by the infiltration of these folds with lymphoid cells during the latter part of fetal life. At birth sections of this region show a pseudostratified epithelium, resting on a broad band of connective tissue containing ill defined masses of lymphoid tissue and numerous small mucous glands. During the first year the lymphoid tissue is greatly increased, and definite follicles with germinal centers are formed.

The pharyngeal tonsil reaches its maximum development in the sixth year according to the observations of Symington.[126] When at its greatest development it may be 30 mm. long and 15 mm. broad and may, in normal cases, project half-way across the cavity of the nasal pharynx. Involution of the pharyngeal tonsil, according to Symington, begins at six or seven years and is completed before puberty but occasionally the organ may persist to maturity. The bursa pharyngea commonly persists throughout adult life, often in the form of a small closed cyst.

The Palatine Tonsils (Figs. 112, 113)

At the time of birth the palatine tonsils have generally lost their simple fetal form and show many of the variations in shape and relation to the surrounding structures which are seen in the adult. Only the most common form of the tonsil is described below. For detailed descriptions of the numerous variations the reader is referred to the papers of Mosher[153] and Grünwald.[90]

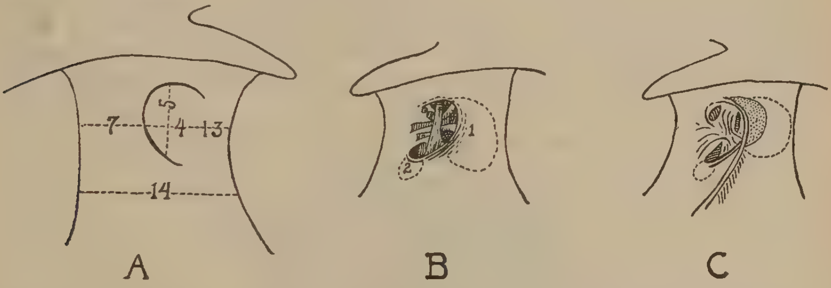

Fig. 112.—Drawing illustrating the position and form of the tonsil in the newborn. A., medial view of the right tonsillar region, average dimensions of different parts indicated in mm. B. and C., lateral views of tonsils at birth showing the position and extent of the commoner peritonsillar fossæ.

At birth, as in later life, the tonsil is lodged in the tonsillar sinus between the two palatine arches and the lateral margin of the tongue. The tonsillar sinus is relatively short and broad in the infant and a fold of mucous membrane, the plica triangularis, is reflected from the anterior palatine arch across the upper part of the tonsil. The plica triangularis ends in a free edge which ordinarily forms about three-fourths of a circle around the tonsillar mass, bounding it except for a small portion of its posterior border. As a rule, the upper third of the tonsil is covered by the plica triangularis in the newborn (Mosher). A number of fossæ may be found between the plica triangularis, the tonsil, and the floor of the tonsillar sinus. In the infant the commonest fossæ are an anterior and superior one, corresponding in part to the supra-tonsillar fossæ of the adult, and a smaller inferior one which projects downward from the posterior-inferior quadrant of the tonsil.

The tonsil as a whole lies higher in the tonsillar sinus than in the adult and its axis is horizontal instead of vertical as in the latter. It is placed more medially, *i.e.*, closer to the soft palate than in later life. The tonsil descends somewhat in infancy and its axis changes from the horizontal to the vertical position in the first two or three years of life.

Lymphoid tissue is found underlying the tonsillar epithelium in the sixth fetal month but definite lymphoid nodules are not formed until about the time of birth, and often germinal centers do not appear until the end of the first post-natal month. The tonsillar epithelium is invaded by lymphocytes before birth but according to Goslar,[89] they are not found in the cavities of the tonsillar crypts until a week or so after birth. Plasma cells also are not found in the tonsils until several days after birth (Davis[77]).

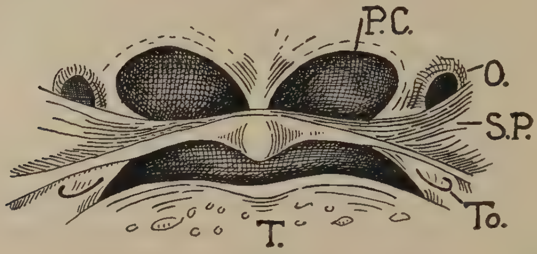

FIG. 113.—Soft palate and surrounding structures of the newborn as seen in posterior view. O., ostium of auditory tube; P.C., posterior choanæ; S.P., soft palate; T., tongue; To., tonsil. (After Mosher.[113])

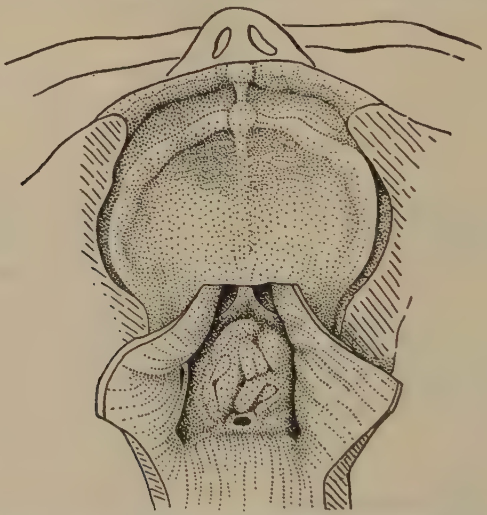

FIG. 114.—Dissection of the mouth and pharynx of a male child one month old, showing the hard palate, the pharyngeal tonsil and the pharyngeal bursa. (Considerably modified from Schwabsch, Arch. f. mikr. Anat., Bd.[29])

The changes which the tonsils undergo in the latter part of childhood are still little known. Genter (quoted by Gundobin[7]) found the weight of the tonsil in the newborn to be 0.75 gms. It increases rapidly to 0.4 gms. in the second year and to 0.8 gms. in the fifth year. In the second decade the average weight is slightly over 1 gm., and in the third and fourth decades nearly 1.5 gms. No decrease in weight was observed until the fifth decade. These figures however are based on weighings of the entire tonsil including its surrounding and interstitial connective tissue. They give us no indication of the amount of lymphoid tissue present in the structure at different ages. Hett and Butterfield[94] conclude from the study of a large series of sections of the tonsils of children that the tonsil normally begins to atrophy at or soon after five years. The majority of observers would set a later date for the beginning of involution in these structures.

THE ESOPHAGUS

The esophagus in the newborn varies in length from 8 to 10 cm., measuring from the cricoid cartilage to the cardia. This length doubles during the first three years of life. Thereafter the increase is slow, the adult of length 23 to 30 cm., being attained some time after puberty. In the newborn and young infant the esophagus is slightly more than one-fourth of the combined length of the head and trunk while in the adult it is equal to about one-sixth or one-seventh of the length of the head and trunk. The length of the esophagus from the incisor teeth, which is of more practical importance, is given in the table of Stark quoted below.

TABLE 10.—THE LENGTH OF THE ESOPHAGUS IN CHILDHOOD (AFTER STARK)

Age	Total length centimeters	Distance, in centimeters, from incisor teeth (or margin of gum) to the level of		
		Cricoid cartilage	Bifurcation of trachea	Cardia
Birth	10	7	12	18
1 yr.	12	10	14	22
2 yrs.	13	10	15	23
5 yrs.	16	10	17	26
10 yrs.	18	10	18	28
15 yrs.	19	14	23	33
Adult	25	15	26	40

At birth the average diameter of the esophagus, as measured with the sound, is 5 mm. The caliber of the esophagus in childhood has been measured by means of sounds by Lesbini[106] and by Schkarin (quoted by Gundobin[7]). The former found the maximum diameter in children from two to five years to be 15 mm., from 12 to 16 years 20 mm., and over 16 years 21 mm. The latter found the diameter in children under two months to be from 7 to 8 mm., between six and nine months 9 mm., between nine months and two years 10 mm., and from 6 to 12 years 12 mm. The wide divergence in these two sets of measurements probably represents only the great natural variation of the esophagus in this respect.

In the newborn the superior limit of the esophagus lies at the level of the fourth or fifth cervical vertebra, and the inferior margin at the ninth thoracic vertebra. Thus both the upper and lower end of the tube lie from one to two vertebræ higher than in the adult. The curvatures of the esophagus, while present in the infant, are less pronounced than in the adult. The same statement holds true for the normal esophageal constrictions.

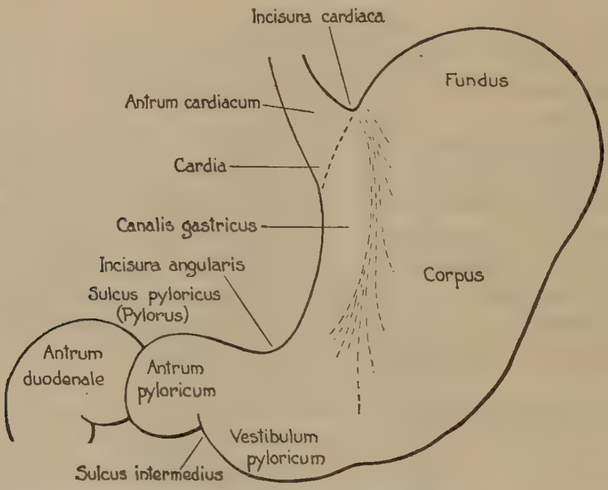

Fig. 115.—Diagram illustrating the divisions of the stomach. (After Lewis.[108])

The esophagus at birth is lined with a stratified squamous epithelium which is distinctly thinner than that of the adult and which may present small scattered areas covered by a superficial layer of columnar ciliated cells. The epithelium rapidly thickens after birth and the ciliated areas, when present, disappear. Both the deep and the superficial esophageal glands are present at the time of birth. The former are less numerous than in later life and their end-pieces are only in the process of formation. The muscularis mucosa is relatively thick in the infant.

THE STOMACH (Figs. 115, to 124, 127, to 130, 147, 156)

Our conceptions of the form of the stomach have been greatly modified in recent years by studies of material hardened in situ and still more through the evidence furnished by the Roentgen ray method. Indeed some investigators would go so far as to say that no definite form can be assigned to the organ because of its varying form in relation to gastric contents and to the waves of contraction which pass along it. This is hardly true, for Lewis' study on the development of the stomach shows conclusively that all of the subdivisions which have been demonstrated in the adult, by strictly anatomical methods of investigation and by the Roentgen-ray, are present in the fetal organ, long before it is influenced by gastric contents or, so far as we know, by physiologic waves of contraction. As much of the

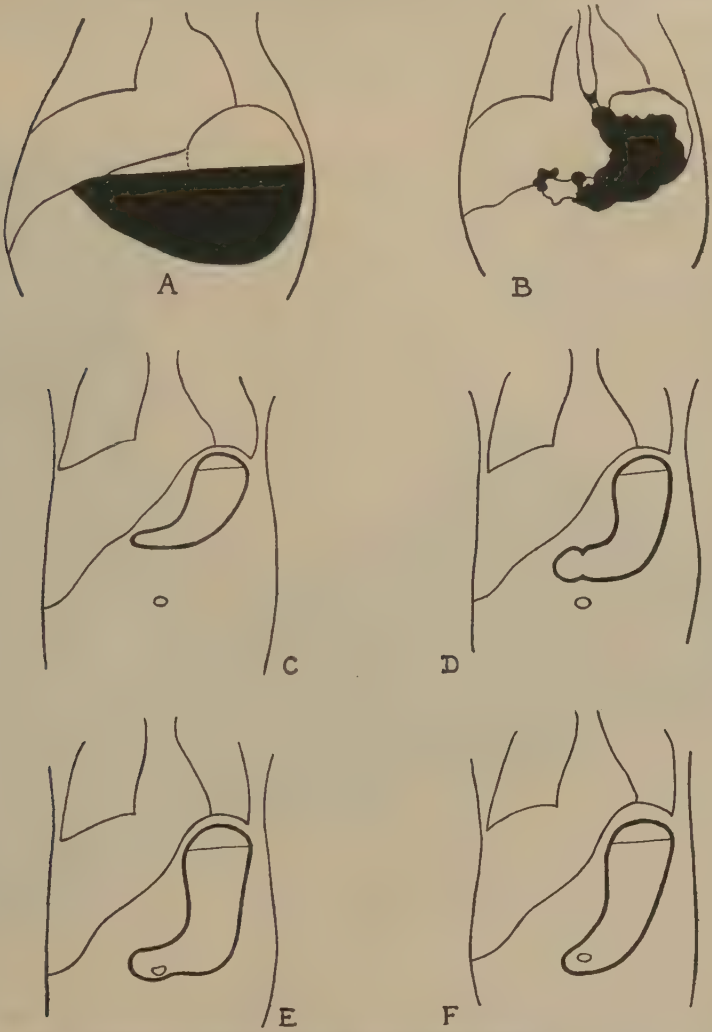

Fig. 116.—A series of outline tracings of radiographs of the stomach in childhood. A, child of five months. B, child of three months. C, child of eight months. D, girl of seven years. E, boy of nine years. F, girl of 12 years. All radiographs taken with the stomach moderately distended and the subject in the erect position. (A and B after Major, 110. C–F, after Flesch and Péteri.[87])

confusion regarding the form of the stomach is due to conflicting nomenclature I adopt for the following description that proposed by Lewis[108] which is illustrated by Fig. 115. All of the divisions of the organ shown in this figure are usually recognizable in the newborn if one examines material which has been properly hardened in situ or fresh specimens which are moderately contracted (Figs. 117, 147). The divisions of the pyloric portion are usually particularly clear and the sulci bounding them well marked.

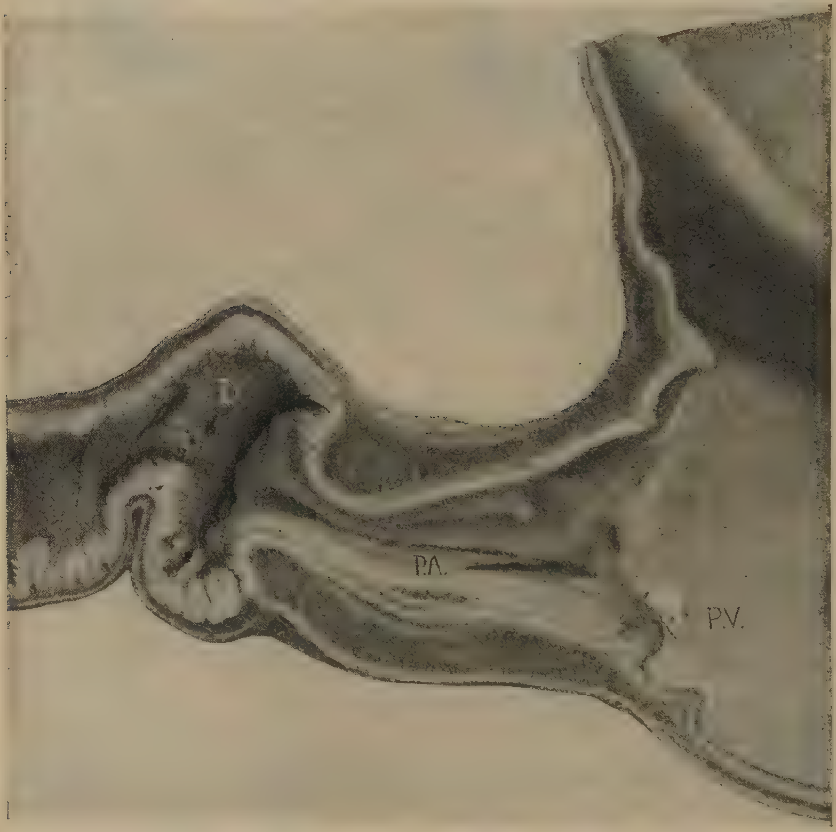

Fig. 117.—A longitudinal section of the pyloric end of the stomach and the duodenum of a full-term child one day old. D., duodenum; P.A., pyloric antrum; P.V., pyloric vestibule (pyloric canal). Twice natural size.

The older anatomical accounts of the form and position of the infant's stomach and the results found by radiographic studies are radically opposed. Almost all anatomists describe the stomach of the newborn and infant as placed vertically with the greater curvature to the left and the lesser to the right. They also generally include the statement that the infant's stomach lacks a fundus. On the other hand radiographs of the suckling's stomach, taken with the subject in the erect position, practically always show the stomach lying transversely in the body with the greater curvature forming its lower margin and with a distinct fundus which extends upward some distance above the cardia and is occupied by a gas bubble. The form, then, of the slightly or moderately distended infant's stomach as seen in *x*-ray has been aptly described as that of an inverted retort. The discrepancy in these two classes of descriptions is due, I think, to the fact that anatomists have generally examined stomachs either in a high degree of contraction or those of premature infants or fetuses which have never been even moderately distended. In still-born children the widest variation in the amount of gastric contents is found. The walls of the sac may be almost in contact or the organ may contain 20 c.c. or more of mucus. In almost all cases of the latter type which I have observed, the long axis of the stomach was either oblique or transverse. At birth the gastric contents is greatly increased, at first by the introduction of air, which begins with the first inspiration, and later with fluid. If the transverse position of the stomach has not previously been established by the accumulation of gastric mucus it is brought about at this time by the factors I have just mentioned. The change in the direction of the stomach's axis is due not to the actual shifting of the viscus as a whole but to the expansion of the lower part of the corpus and particularly of that portion which lies to the left. The fundus is well established long before birth but it also shares somewhat in the expansion of the left part of the corpus following the increase in gastric contents.

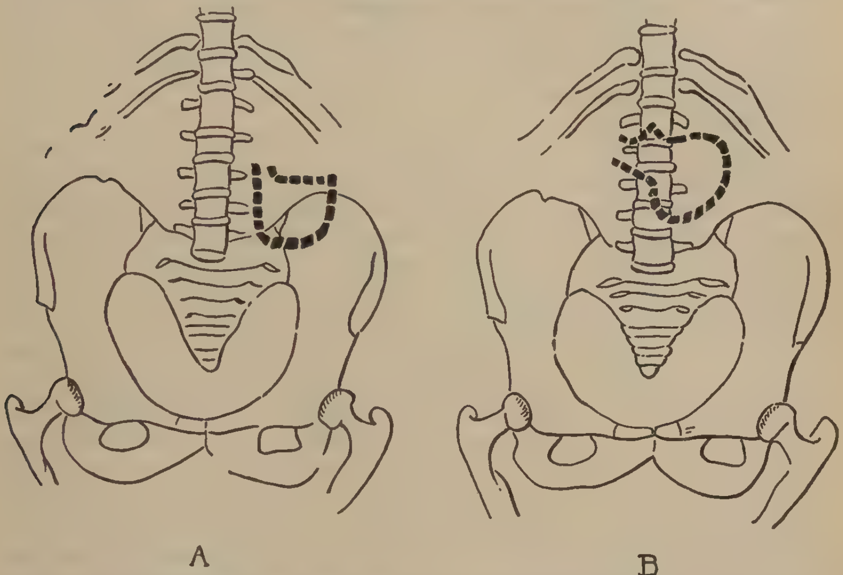

FIG. 118.—Outline tracings of radiographs showing the position of the stomach in relation to the skeleton in later childhood. (After Sever.[123])

According to radiographic studies, the transverse position of the moderately filled stomach is only characteristic of early infancy. In the second or third year the "cows-horn" form described by Holzknecht for the adult, and somewhat later the "fish-hook" or "sink-drain" form described by Rieder, become the more common types. In other words, the stomach tends to return to the vertical position seen in the fetus. Possibly this change is brought about in part by the effect of gravity as the child begins to assume habitually the erect posture, and in part by the growth of the lesser pelvis which permits a portion of the small intestines to pass into the pelvic cavity and thus leaves more space for the stomach to sag downward in the abdominal cavity.

With these changes in form and direction of the axis of the stomach the position is also modified. While the stomach retains its transverse position its lowest point, which is in the greater curvature, rarely lies below the umbilicus even when the viscus is well distended. With the development of the "cows horn" form the pyloris generally lies at the umbilicus or a little below it. Later, with the development of the "fish-hook" form, there is still a greater descent and Sever[123] found that in a large series of children averaging 10 to 11 years old who were apparently normal, the lowest point of the stomach varied from the fourth lumbar vertebra to a point well below the iliac crests. This position is lower than that ordinarily found in the adult and if this author's observations are correct there must be some ascent of the stomach between puberty and maturity.

Gastric Capacity.—The capacity of the stomach in infancy has been tested by a large variety of methods. These may be divided into two classes, the physiologic and the anatomic. The physiologic method of weighing the child before and after feeding is, on the whole, distinctly the more accurate, since it allows the selection of any number of cases of which the condition and antecedents can be accurately known; and also because single cases may be studied over a considerable period of time. The disadvantages of this method are the inability to determine accurately the degree of distension of the stomach, without recourse to the *x*-ray, and the possibility of over estimation of the weight of the gastric contents through the inclusion of the weight of milk which is retained in the esophagus or which has passed into the duodenum.

These possibilities of error are negligible in comparison to the great advantages of the method. The anatomic method consists of introducing into the stomach of the cadaver some substance which can be easily measured and then determining the amount required to fill the organ. Many modifications of this method have been employed, chiefly with an eye to securing a "normal" expansion of the stomach.

Thus Holt[95] distended the viscus until the rugæ disappeared, Muggia[115] and Pfaundler[118] filled it at varying degrees of water pressure and Mosenthal[112] introduced water into the stomach in situ until the organ filled its place in the abdominal cavity. Perhaps the simplest and best anatomic method is that of Zuccarelli[140] who removed the stomach from the body, distended it with water, and then plunging the organ into a vessel of water opened its orifices. As soon as the pressures of the water within and without the organ had adjusted themselves the openings of the organ were again clamped, the organ removed and its content measured by pouring it into a graduated vessel. Anatomic methods of measuring gastric capacity have the grave disadvantage of being applicable only to material which is often pathologic and of giving results which are dependent in a considerable measure on the degree of contraction of the stomach at the time of death. It is only when a large series of measurements of this type are available that the results are of much value, and then their worth is only a relative one.

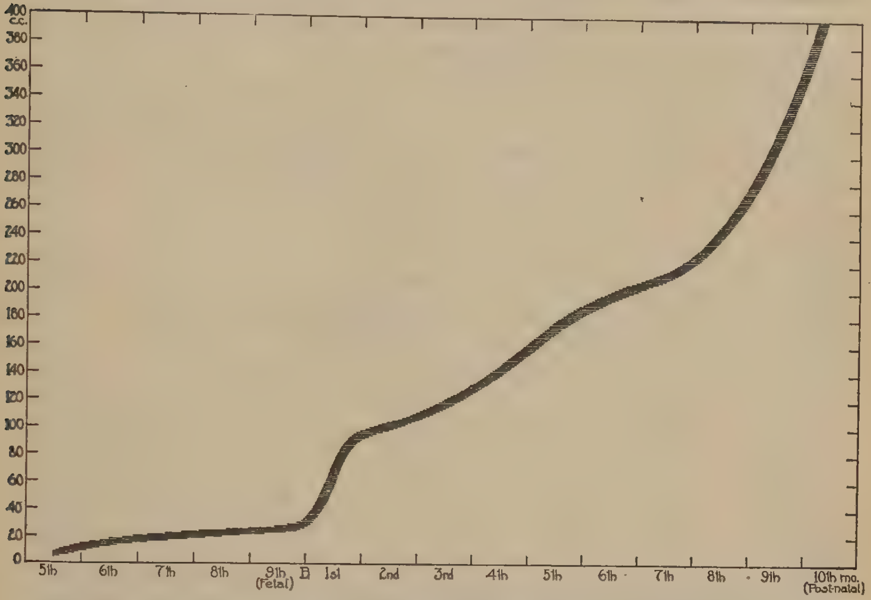

Fig. 119.—A semi-diagrammatic graph illustrating the increase in gastric capacity in c.c., as determined by anatomic methods, from the fifth fetal month to the end of the first year. (Based upon the data of Alliot, Borie, Dargien, Muggia, Zuccarelli and others; and on material collected by the writer. Total ca. 200 cases.)

The chief advantage of the anatomic method is that it is possible to investigate the gastric capacities of fetuses and of older children, which cannot be studied by the physiologic method.

The average anatomic capacity of the stomach, as determined by Zuccarrelli's method, is about 10 c.c. in the fifth fetal month. It rises rapidly to about 20 c.c. by the middle of the sixth fetal month but thereafter the increase to the close of prenatal life is rather slow. In the full-term newborn the average anatomic capacity lies between 30 and 35 c.c. This rises to about 45 c.c. in the middle of the first week, and to about 75 c.c. in the second week. At the end of the first month of post-natal life the average capacity, as determined by all anatomic methods, is about 100 c.c., or nearly three times that of the child at birth. Following the first month there is a period of slow increase in anatomic capacity which extends nearly to the end of the third trimester. During this period the actual capacity is slightly more than doubled, and the rate of increase is about 30 per cent. per month or about one-tenth that observed in the first four weeks of extrauterine life. At the eighth month the curve of anatomic capacity rises rapidly probably through the increase of a number of diastolic stomachs in the material of this age available for study.

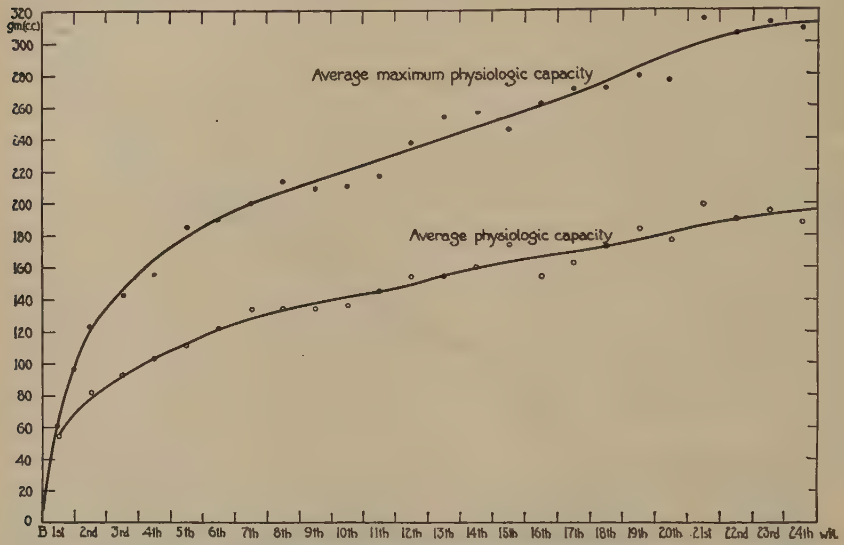

Fig. 120.—Graphs illustrating the changes in physiologic gastric capacity as shown by the feeding records of 11 full-term children most of whom were entirely breast-fed.

The data upon the anatomic capacity in later childhood are less extensive than those regarding the growth in the first year. Probably the average capacity in the second year is not far from 500 c.c., about 550 c.c. in the third year, and in the fourth year about 600 c.c. In the latter half of childhood the average gastric capacity probably lies between 750 and 950 c.c.

The average physiologic capacity of the stomach in the first day after birth is about 7 gm. This rises very rapidly to about 45 gm. on the fourth day when it becomes equal to the anatomic capacity. In the second week the average capacity is about 90 gm. Thereafter until the end of the first year the average physiologic capacity increases at a fairly regular rate of about 20 or 25 c.c. per month. Curves of the average physiologic capacity and the average anatomic capacity run parallel from about the fourth day after birth until nearly the end of the third trimester but the physiologic capacity is generally a little greater than the anatomic capacity as determined by the usual methods.

Curves of the maximum physiologic capacity in the suckling, as determined by averaging the largest meal taken in a given week, are found to agree closely in type with those of average physiologic capacity although the values are at all times from 25 to 50 per cent. greater in the former. Figure 120 shows curves of the average and the average maximum capacity in the first year as determined by the physiologic method.

The increase in the surface area of the gastric mucous membrane during childhood is difficult to determine with any accuracy as it is of course dependent upon the degree of extension of the stomach. The table of Dargien,[75] which is given below, is the most extensive piece of work on the subject. As will be noted from the table, the gastric capacities of the several cases agree fairly well with those determined by other authors and the areas are therefore fairly accurate.

TABLE 11.—THE AREA OF THE GASTRIC MUCOUS MEMBRANE IN CHILDHOOD (AFTER DARGIEN[75])

Age	Length of the greater curvature, centimeters	Gastric capacity, cubic-centimeters	Gastric surface area, square centimeters
Newborn (1)	9.5	32	12.0
Newborn (2)	11.0	36	13.5
Child 2 mos.	13.0	95	31.0
Child 3½ mos.	16.0	120	48.0
Child 5 mos.	17.0	140	55.0
Child 6½ mos.	19.0	145	67.0
Child 8 mos.	19.0	215	82.0
Child 11 mos.	21.0	240	118.0

The Finer Structure of the Stomach.—The mucous membrane of the stomach in the newborn and in early infancy is relatively much thicker than in older children and in the adult. The lining gastric epithelium is composed of a single layer of high columnar epithelium, which is continued into the crypts of the gastric glands. The cells lining these crypts are actively secreting mucus at the time of birth. The true gastric glands are shorter and broader and branch more freely than in the adult. According to the estimates of Toldt,[128] about seven gastric glands open into a single crypt in the newborn. Parietal or acid cells are present although they are not fully differentiated at birth. Fischl[85] found them fully developed by the end of the second year. The total number of gastric glands at birth is estimated by Toldt[128] as almost 2,000,000 as compared with nearly 17,000,000 at 10 years, about 22,500,000 at 15 years, and over 25,000,000 in the adult. As these estimates are based in part upon measurements of the area of the gastric mucous membrane, and as this area is in turn dependent upon the degree of expansion of the stomach the value of these figures is only relative; but there is, without doubt, a tremendous increase in the number of gastric glands during childhood, and a still greater increase in the number of gastric crypts. The post-natal development of the cardiac and pyloric glands has not been investigated in detail. Both Fischl and Toldt state that

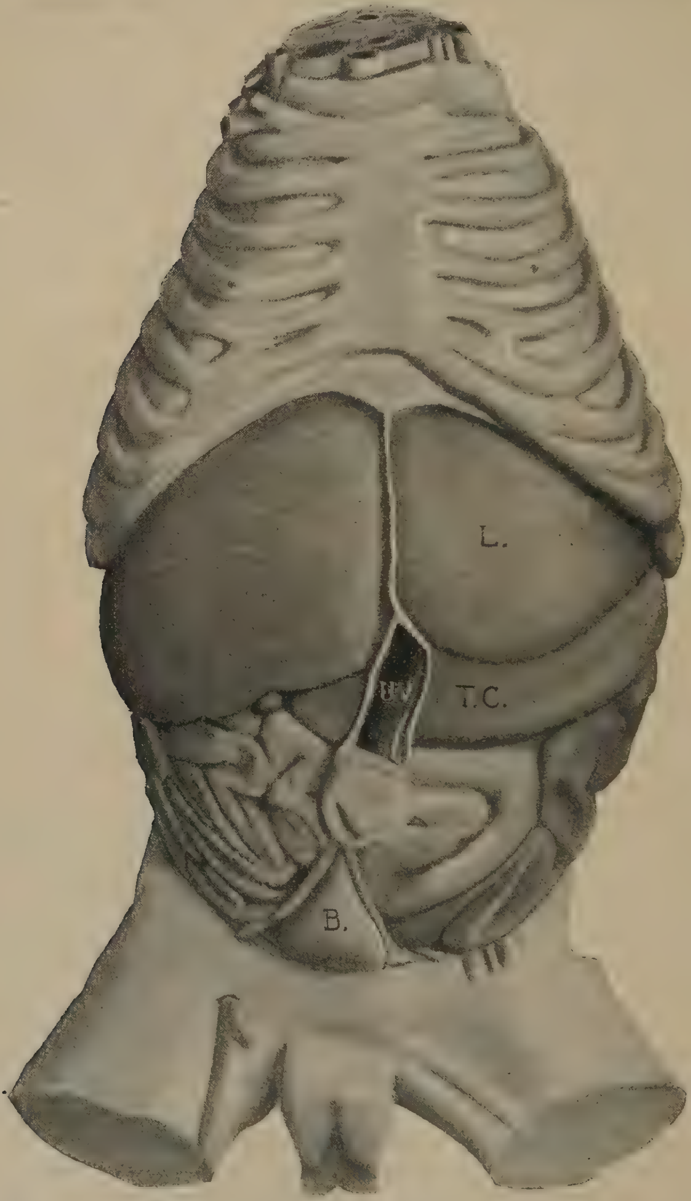

Fig. 121.—Anterior view of a cast of a dissection of the trunk of a full-term, newborn female child. (Drawn from a preparation made by Dr. L. W. Barry.) B., bladder; L., liver; T.C., transverse colon; U.V., umbilical vein. Three-fourths natural size.

parietal cells are not found in the pyloric glands of children but Johnson[98] found them in a fetus of 24 cm.

The musculature of the stomach, aside from that of the pyloric canal and sphincter, is only moderately developed at the time of birth. The longitudinal layer being incomplete over a part of the greater curvature. According to Fishel both layers of the muscularis mucosa are present at this time. The elastic tissue is very poorly developed and is confined mainly to the walls of the arteries.

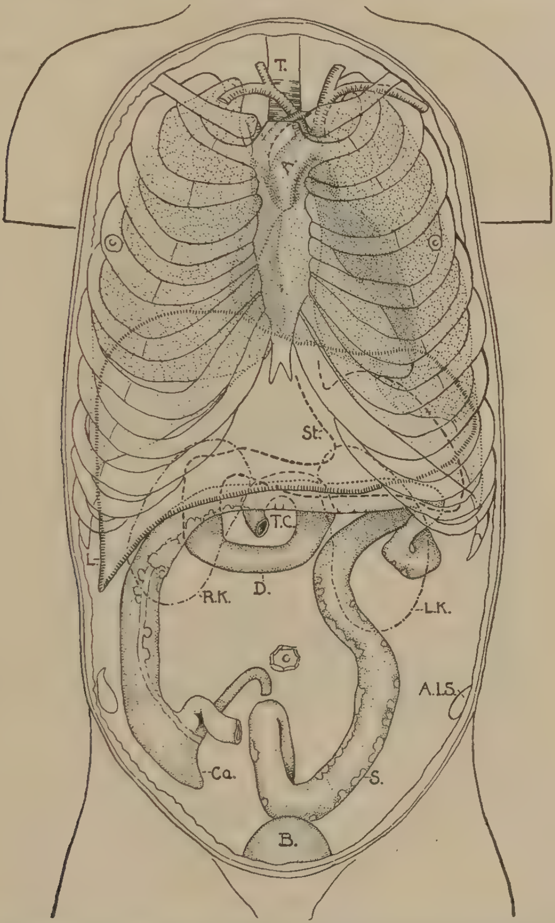

Fig. 122.—A graphic reconstruction, from transverse sections, of the thoracic and abdominal viscera of a boy about five years old. A., arch of aorta; A.I.S., anterior superior iliac spine; B., bladder; Ca., cecum; D., duodenum; L., liver; L.K., left kidney; R.K., right kidney; S., sigmoid colon; St., stomach; T., trachea; T.C., transverse colon. (After Symington.[14])

Lymph-nodules have been observed in stomachs of the newborn but their number is both absolutely and relatively less in childhood than in maturity.

THE INTESTINAL TRACT

The Intestinal Tract as a Whole.—The weight of the intestines, emptied of their contents, is about 10 gm. in the seventh fetal month. During the last two months of fetal life the weight of the intestinal mass increases at a very rapid rate so that the average weight in the full-term newborn is nearly 50 gm. There are no accurate figures, so far as I am aware, on the weight of the intestines in normal children.*

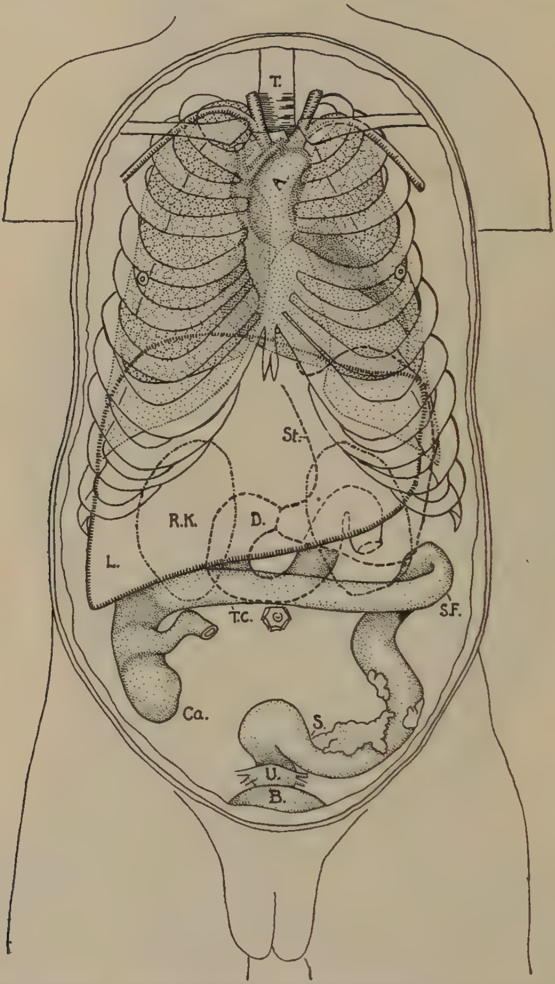

FIG. 123.—A graphic reconstruction, from transverse sections, of the thoracic and abdominal viscera of a girl about five years old. A., aortic arch; B., bladder; Ca., cecum; D., duodenum; L., liver; R.K., right kidney; S., sigmoid colon; S.F., splenic flexure; St., stomach; T., trachea; T.C., transverse colon; U., uterus. (After Symington.[14])

* A small series of weighings of the intestines of children has been published by Muhlmann. But Muhlmann's figures on the weight of the intestines in the newborn and adult are so different from those of other observers that the value of the whole series can probably be questioned.

In the adult Messedaglia and Vainanidis found the average absolute weight to be approximately 490 gm., nearly 10 times greater than that of the child at birth. The relative weight of the intestinal mass decreases from about 1.5 per cent. in the infant to about 0.75 per cent. in the adult.

The length of the intestines at birth is quite variable and this variation does not seem to be intimately associated with that of body length or weight. In 25 full-term newborn children I find the average length of the total intestinal tract, from pyloris to anal canal, to be 338.5 cm. In this series the maximum length was 461 cm. and the minimum 336 cm. This average is somewhat greater than found by most observers, probably because all premature children were ruled out. The intestinal tract increases about one-third in length during the first year of life. Thereafter the growth is much slower. The absolute length of the intestines in the adult is approximately twice that of the newborn. The ratio of the length of the intestine to the length of the entire body is much greater in the infant than in the adult. The ratio in my series of newborn children was as 8.3 :1 and in Messedaglia's and Vainanidis' series of adults as 5.4 :1. Beneke[68] found the ratio in the adult to be still lower (4.5:1). This change in the relative length of the intestine is not due so much to the reduced rate of lineal growth of the intestine as to the rapid growth of the lower extremities for if the length of the intestine is compared with that of the trunk less change is observed. Thus Debele[78] found this relation in children of the first month to be 1:16.6, in those of the entire first year 1:18.5 and in those between 9 and 10 years 1:15.9. Fehling similarly found little difference between the intestine-trunk ratio in the newborn and the adult. The ratio between the length of the large intestine and small intestine remains almost unchanged throughout post-natal life.

Passow's[117] data show that the surface area of the intestinal tract increases approximately fourfold between infancy and maturity. This result is based on gross measurements of the inner surface area of the canal. The actual increase in intestinal epithelial area is actually somewhat less, as there is a relative decrease in the number of intestinal folds and villi after birth.

Further details of the dimension and growth of the intestines will be found in the following table and in the paragraphs dealing with the several segments of the intestinal tract.

The shape of the intestinal mass in the newborn and infant is quite different from that of the adult. On opening the abdomen in the infant the intestines present an oval anterior surface bounded above by the liver and left costal margin, and below by the brim of the pelvis. Owing to the great relative breadth of the abdomen and the large size of the lever, the greatest diameter of the anterior surface of the intestinal mass is transverse in the infant whereas it is vertical in the adult. The mass is indented in the anterior median line by a wedge shaped depression which is occupied by the large abdominal portion of the bladder. In medial sagittal section, the intestinal mass appears as an acute scaline triangle with its base formed by the anterior abdominal wall, its shorter side by the inferior surfaces of the stomach, spleen, and liver; and its longer posterior side by the psoas and iliacus muscles, the spine and the iliac crests, and the kidneys and suprarenals. In the newborn the intestines are almost equally divided between the right and left sides of the abdominal cavity. The rectum usually is the only part of the intestines which lies in the pelvic cavity at birth. It is not until after infancy that any considerable part of the small intestines descends into the lesser pelvis.

The Finer Structure of the Intestinal Tract.—The most striking characteristic of the infant's intestine, as seen in section, is the comparatively weak development of the muscular layers. In the child at birth and for sometime thereafter the mucosa, submucosa and muscularis are of equal thickness. In the adult the muscularis is as thick as the mucosa and submucosa combined. The longitudinal layer of muscle is particularly thin in the newborn. These observations hold good for the entire intestinal tract.

In the newborn the villi are distributed the entire length of the small intestine as in the adult. The villi increase rapidly in number during the later part of fetal life according to the observations of Johnson. Hilton has estimated the number in the newborn at 1,000,000 whereas the number present in the adult intestine is generally estimated at from 4,000,000 to 6,000,000. Nothing is known of the rate of increase in post-natal life or when this increase ceases.

The intestinal glands or crypts of Lieberkuhn are but half as long although almost as thick in the newborn as the adult. Their number increases greatly during childhood. This is probably brought about mainly by the longitudinal division of existing glands, and not by the evagination of the surface epithelium of the intestine. At the time of birth many glands are apparently in the process of division being bifurcated at their bases. Goblet cells are quite as numerous in the intestinal glands of children as of adults.

The post-natal development of the duodenal glands or glands of Brunner has never been studied in detail. They are said to be smaller and less branched in the newborn than in the adult.

Lymphoid tissue is present both in the large and small intestine at the time of birth. As a rule, it is in the form of diffuse masses without definite germinal centers. There is a marked increase in the amount of lymphoid tissue during the first year, and germinal centers generally make their appearance within a few weeks after birth. Passow[117] found the relative number of both solitary and aggregated lymph-nodules (Peyer's patches) greater in children than in adults. The existence of lymph-nodules in the appendix at birth has been denied by some investigators but they are certainly present at this time as is shown by the studies of Sudsuki[125] and Johnson[99] and by the reconstructions of Hines, one of which is reproduced in Fig. 125.[31] There is, no doubt, some increase in the number of nodules in the appendix during the first year as in other parts of the intestinal tract.

The elastic tissue of the intestine of the newborn is confined almost entirely to the walls of the blood vessels. It increases greatly during the first few months of post-natal life.

The distension of the large intestine by meconium in the latter part of fetal life has a marked effect upon the structure of its walls. All of the layers are reduced in thickness, the intestinal glands become much shorter and broader and the intervals separating them are increased. The villi, which are present in the large intestine during the greater part of fetal life, are also shortened, broadened and separated. These changes are described in detail by Johnson.[99]

The Small Intestine (Figs. 121, 122, 123, 132, 147, 151, 155).—The small intestine is from 300 to 350 cm. in length in the full-term newborn child (average of 25 cases 338. 5 cm.). Its length increases about 50 per cent. in the first year of life and is approximately doubled by puberty. Great individual variations in the length of the small intestine are encountered in children.

The arrangement of the intestines in the newborn has been studied by Mall[111] on hardened material. He found the attachment of the mesentery to be along a curved line extending from the left hypochondriac region to the right iliac fossa. The intestines were arranged in coils along this line crossing and recrossing it. The convolutions lying above and to the left of the mesentery were arranged in coils with their planes at right angles to the body while those lying below and to the left were arranged with their planes perpendicular to the body (Fig. 121).

The duodenum is from 7.5 to 10 cm. long at birth. The annular type of duodenum is the commonest in the newborn and suckling although the U-shaped type is seen occasionally. The superior end of the duodenum in the newborn lies at the level of the first lumbar vertebra, or the intervertebral disc below it. The inferior end lies at the same level or a little lower. The loop of the duodenum extends from 1 to 1.5 cm. to the right of the median line and is often directed downward so that the lowest point on the loop may lie no more than a centimeter above the right iliac crest. The inferior end of the duodenum is often lodged in the notch in the lower border of the stomach between the pyloric vestibule and the pyloric antrum. Figures 132, 147 show the form and relations of the duodenum in the late fetus and newborn.

The Large Intestine (Figs. 121, 122, 123, 124, 125, 126, 127, 129, 132, 147, 151, 153, 155).—The cecum in the infant is much smaller relatively as well as absolutely than in the adult. Charpy, in a series of newborn children, found the average capacity to be 2.5 c.c., the average length 15 mm. and the average breadth 17 mm. Thus, as in the adult, the cecum of the newborn is broader than it is long. At birth the cecum almost always presents a smooth external surface. Two main types can be recognized: First, the "dropped cone" type in which the cecum tapers gradually into the vermiform process which

TABLE 12.—THE LENGTH OF THE INTESTINE

(Based on the Data of Brandt, Arnoljevic, Debele, Weinberg, Valtorta, Messedaglia and Vainaindio, and Scammon)

Age	Number of cases	Length of large intestine in centimeters	Length of small intestine in centimeters	Length of total intestine in centimeters	Relation of length of large intestine to length of small intestine	Relation of body-length to intestine-length	Relation of trunk-length to intestine-length
8th fetal month	7	46.4	249.1	278.5	1:5.3	1:7.3	
9th fetal month	9	62.5	283.7	340.8	1:4.5	1:8.3	
10th fetal month	15	64.5	301.5	366.0	1:4.6	1:8.1	
Birth	25	66.0	338.5	402.6	1:5.1	1:7.9	
1 to 3 months	25	67.9	337.4	405.3	1:4.9	.....	1:18.7
3 to 6 months	15	70.7	380.9	451.6	1:5.3	.....	1:18.0
6 to 12 months	9	83.1	418.1	501.2	1:5.0	.....	1:18.5
1 to 2 years	6	88.9	460.4	549.3	1:5.1	.....	1:17.2
2 to 4 years	6	88.1	468.6	556.8	1:5.3	.....	1:17.3
4 to 6 years	10	99.9	469.9	569.8	1:4.7	.....	1:14.4
6 to 8 years	7	108.5	500.6	609.1	1:4.6	.....	1:14.3
8 to 10 years	7	116.4	579.0	695.4	1:4.0	.....	1:15.9
Adult	14	160.7	753.9	914.6	1:4.6	1:5.3	

lies directly below it; and second, the "b-type" in which the lower extremity of the cecum together with the vermiform process, is bent upward at an acute angle with the upper part of the sac. The "b-type" is much the commoner of the two. No sharp line of demarkation can be recognized between the cecum and vermiform process in the majority of infant specimens; the cecum tapers into the process through an ill-defined conical termination which Parsons[116] has termed the conus appendicis.

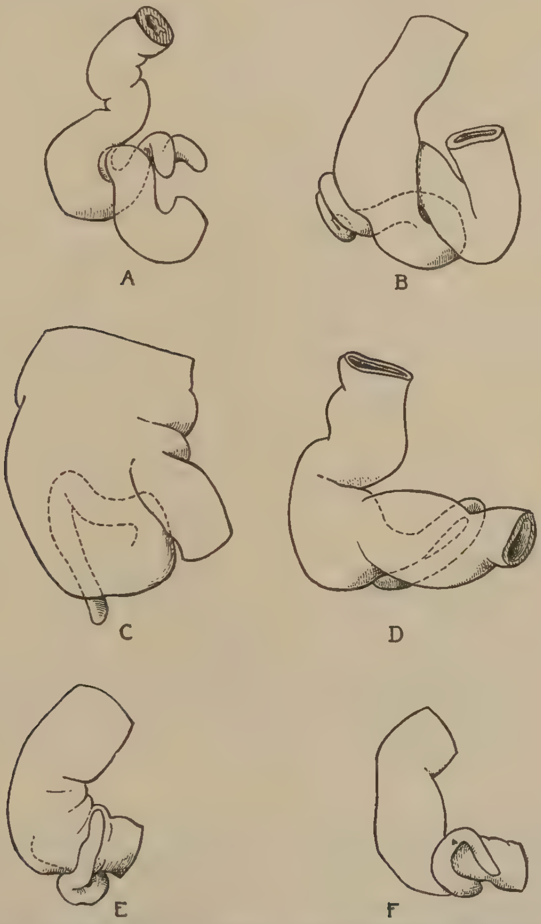

Fig. 124.—Six examples of the cecum and appendix of the newborn. These specimens were taken at random from the autopsy room and have not been selected to show unusual variation. All natural size.

The taenia of the cecum are present but ill-defined at the time of birth. The haustra are absent in the newborn if the intestine is distended with meconium but appear in the first six months of postnatal life. With the development of the haustra the sacculations of the cecum make their appearance but it is not until the third or fourth year that the typical sacculated cecum of the adult is fully differentiated.

Toldt[129] has pointed out that the ilio-cecal valves are produced by the bending of the cecum and vermiform process upon the colon. This process takes place in early fetal life so that the leaves the valves are well established before birth. They increase greatly in length in the later fetal and the early post-natal months.

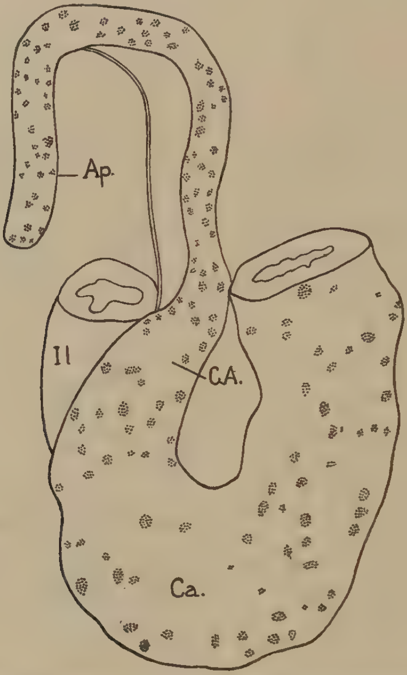

Fig. 125.—A graphic reconstruction, from transverse sections, of the cecum and appendix of a full-term, still-born child showing the number, form and distribution of the lymphoid masses which are indicated in stipple. Ap., appendix; Ca., cecum; C.A., conus appendicis; Il., ileum. Twice natural size. (Reconstruction by Dr. Charles Hymes.)

Contrary to the common opinion often expressed in text-books, the position of the cecum in infancy and childhood and is not more elevated than in the adult. This is strikingly shown in the table of findings of Legueu[105] which is given below. The observations of other investigators, including my own, confirm those of Legueu. Vallée[131] found the cecum below the right anterior superior iliac spine in nearly three-fourths of the hundred infants which he examined. Smith,[271] in a series of over 1000 autopsies on infants, found the cecum undescended in about 6 per cent., in the right iliac fossa in about 85 per cent., and in the pelvis in nearly 10 per cent.

The axis of the cecum is usually either vertical or else ascending and directed a little to the right. The posterior surface of the cecum in infancy is generally in contact with the lower part of the right kidney, the crest of the ilium, and the upper part of the ilio-psoas muscle. The anterior surface is covered by coils of the small intestine and often by a loop of the sigmoid flexure of the colon.

Table 13.—The Position of the Cecum in Infancy (After Legueu[105])

Age	Sex	Number of cases	Position of cecum					
			Lumbar		Iliac		Pelvic	
			Number	Per cent.	Number	Per cent.	Number	Per cent.
Birth to three years	m.	32	2	6	25	78	5	16
	f.	18	1	6	10	56	7	39
	Both	50	3	6	35	70	12	24
Adult.....	m.	100	3	3	82	82	15	15
	f.	100	1	1	62	62	37	37
	Both	200	4	2	144	72	526	26

The appendix or vermiform process of the newborn varies in length from 2 to 8 cm. Extraordinary cases having a length of 10 cm. or more have been reported. The statement, occasionally made, that in relation to the large intestine the appendix is relatively longer in

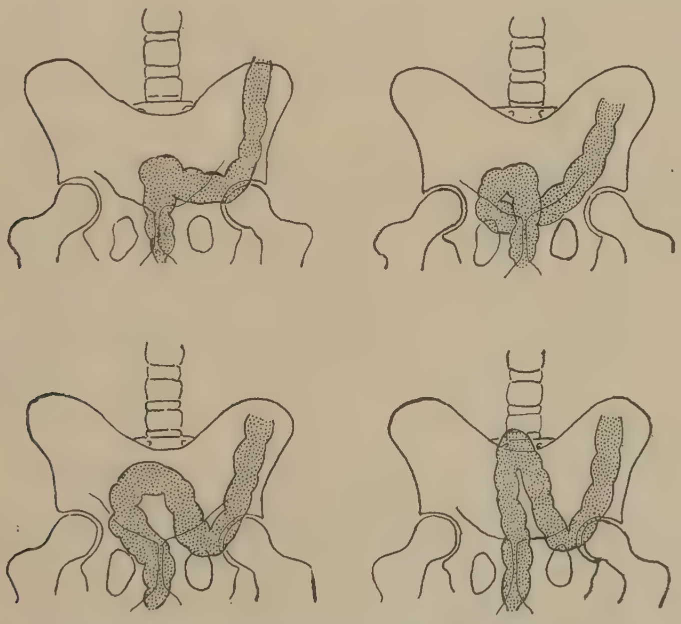

Fig. 126.—Four radiographs showing the form and position of the rectum and sigmoid colon in infancy. (After Peteri, Jahrb. f. Kinderheilk., Bd. 82.)

the infant than in the adult is not verified by the data I have examined. The diameter of the appendix at birth varies from 2 to 6 mm. The appendix increases in length quite rapidly during the first year of life attaining an average length of from 8 to 10 cm.; thereafter its growth is very slow and irregular.

As stated in the section on the cecum, the appendix is generally connected with the cecum by an enlarged and rather indefinite basal segment, the conus appendicis.

The direction of the appendix in the suckling is as variable as in the adult. In a hundred infants examined by Vallée it was found to be horizontal in 32 per cent., oblique in 10 per cent., vertical-ascending in 34 per cent., and vertical-descending in 24 per cent.

In some hundred and fifty cases collected by Liertz,[109] Vallée,[131] and the writer, the appendix lay medial to the cecum in one-half, retrocecal in one-third and free below in over one-tenth of the instances. The remainder were irregular in position but in only two cases in the series, one a premature, was the appendix lateral to the cecum. Vallée found the appendix lying above the anterior superior iliac spine in 72 per cent., below the spine in 22 per cent. and in the true pelvis in 6 per cent. of his hundred cases.

The opening from the appendix to the cecum may be guarded by a crescent-fold of mucous membrane known as the valve of Gerlach (Valvula processus vermiformis *BNA*). Sudsuki[125] found this structure present in over half of the appendices of children of 10 years or younger which he examined; and present in slightly less than one-fourth of the adults.

The ascending colon is relatively as well as absolutely shorter in the newborn and suckling than in the adult. This is due not to the position of the cecum, which is at least as low as in maturity, but to the small dimensions of the lumbar region. The ascending colon may either pass directly upward or, more commonly, upward and to the left. Posteriorly, the ascending colon is in contact with the left kidney and the lower part of the right suprarenal. The anterior relations vary considerably: Sometimes the entire ascending colon lies under the cover of the left lobe of the liver, but usually a few coils of the small intestine come in contact with the lower part of its inferior surface.

Because of the frequent obliquity of the ascending colon the left colic or hepatic flexure is often poorly marked.

The transverse colon is relatively long in the young infant. It may pass straight across the abdomen, form a gentle curve with its convexity directed downward, or be thrown into a series of short abrupt curves. In the newborn the transverse colon may lie entirely under the cover of the liver but ordinarily it projects below the margin of the left lobe from a point a centimeter or so to the left of the median line. The greater part of this projecting portion comes in direct contact with the anterior abdominal wall, for the greater omentum is not developed sufficiently at this time to fully cover it (Fig. 121).

The transverse colon is in contact with the duodenum, with the head of the pancreas, often with the anterior surface of the kidney posteriorly, and with the stomach and first part of the duodenum superiorly.

The splenic, or right colic, flexure is well marked in infants. According to the observations of Fleury,[320] it generally reaches the level of the ninth or tenth rib, while in adults its apex usually lies at the level of the seventh or eighth rib. Contrary to the usual description of the splenic flexure, I find that the colon is almost always in contact with the spleen at birth and that its impression forms a considerable area on the medial side of that viscus.

The descending colon is comparatively short. It is in contact with the left kidney and the quadratus lumborum.

The sigmoid colon is the most striking part of the large intestine in the newborn. It is generally enormously distended with meconium and, as the lesser pelvic cavity is too small to contain any considerable part of it, it projects far upward into the abdomen. The sigmoid colon may take a variety of forms for which several classifications have been suggested. Following that proposed by Bourcart,[70] three main types can be recognized—the ascendant, the transverse, and the descendant. The ascendant type is by far the commonest—being found in 80 per cent. of all cases by Bourcart and 75 per cent. by Gysi.[91] In this type three intestinal loops are formed. The first is small with its apex directed downward, and lies in the left iliac fossa. It passes over into the main loop which is directed upward into the abdominal cavity and which may reach the level of the umbilicus or even higher. The descending limb of the main loop joins the small third loop which passes into the lesser pelvis. In the second type, the main loop of the sigmoid passes transversely across the lower part of the abdomen and its apex is lodged in the right iliac fossa. Twenty to 25 per cent. of sigmoid flexures are of this variety. In the third type, which is quite unusual, the sigmoid passes directly over the left iliac fossa into the lesser pelvis. The main loop of the sigmoid colon is almost always in front of the small intestines and in contact with the anterior intestinal wall. In one-half of all cases a part of the sigmoid colon lies in the right iliac fossa.

The rectum is relatively longer at birth and in early life than in the adult. While the lower part of the tube descends vertically and is straighter in infancy than in later life, the upper portion is usually directed to one side of the pelvis, more commonly to the right. The pars analis recti lies completely below the level of the tip of the coccyx at birth, (Johnson[100]), and the anal opening is somewhat posterior to its adult position. The rectal sinuses and columns, and the transverse rectal folds are all differentiated sometime before birth, although the latter may be temporally obliterated in the newborn by the distension of the upper part of the rectum by meconium. In the infant, the peritoneum extends downward in front of the rectum to the level of the fourth sacral vertebra (Ballantyne[1]).

The Pancreas (Figs. 132, 147, 151, 156)

Until the sixth month of fetal life the pancreas is extremely small both relatively and absolutely. In the sixth month, however, histologic evidences of secretion appear in the gland and with these there is a marked increase in the rate of the growth. In the newborn the pancreas weighs from 2.0 to 2.5 gm. and forms about 0.07 per cent. of the total body-weight. During the first two months of post-natal life the gland apparently increases little in mass; but between three and six months its weight is doubled, and by the end of the first year it weighs about 10 gm. The relative as well as the absolute weight of the pancreas increases during the first year. Between one and three years the gland is again doubled in weight but after the third year its growth is much slower. The weight of the pancreas in the adult is over 30 times that of the newborn.

Microscopic sections of the pancreas at birth show the alveoli arranged in compact masses which are separated by wide connective tissue septa. The alveoli are fewer in number in each lobule, and are smaller individually than in later life; and the smaller ducts are more in proportion to the amount of parenchyma. Secretory granules can be demonstrated in the alveolar cells after the sixth fetal month. The finer vascular supply is noticeably richer in the newborn and in the first few months of life than later.

The relative number of islets of Langerhans is greater in the newborn than in later life. The extensive micrometric studies of Wilms[138] showed a reduction of four-fifths in the relative number of islets per square millimeter of both the head and tail of the pancreas between three months and four years. Clark,[73] whose technique is much superior since he used modern intra vitam staining methods immediately after death, also found a slightly greater relative number of islets in the infant than in the adult. The actual total number of islets is apparently greatly increased. Clark estimated that the number in a child of six months to be 120,323 while the average number similarly estimated for six adults was over 800,000. The reported smaller size of the islets in infancy is open to doubt since they have not been measured after preparation by modern methods. In infancy, islets are found in the interlobular connective tissue and at the peripheries of the lobules as well as within them. The islet cells are smaller and less distinct than later. Their connective-tissue support and capsule is also less developed. Most of the distinguishing microscopic characteristics of the newborn's pancreas disappear during the first year of life.

The pancreas is from 4 to 6 cm. in length and from 1 to 2 cm. in thickness in the newborn. As in the adult, the subdivisions of head, body, and tail can be distinguished although there is no sharp line of demarkation between the last two portions. The head forms a somewhat greater part of the gland in the newborn than in the adult. The surface markings are less pronounced at birth than later, particularly the tuber omentalis which is generally only a small papilla. At this time the pancreas lies at the level of the second or third lumbar vertebræ. The head is enclosed in the loop of the duodenum and comes in relation with the aorta and vena cava behind, and the transverse colon anteriorly. The body is directed to the left and generally upward as well. The tail is either continued upward and to the left in line with the body or, less commonly, is bent downward at a blunt angle to it. The tail and body are triangular in cross-section having superior, inferior, and posterior surfaces. The superior surface is in contact with the stomach and, near the head, with the papillary process of the liver. To the left the posterior surface comes in contact with the left suprarenal or left kidney, generally the former, and with the spleen. The slight changes in the position and relations of the pancreas in later childhood have not been investigated.

Distension of the stomach causes a flattening and widening of the superior and posterior surfaces of the pancreas with a reduction of its inferior surface. Distension of both the stomach and intestines flattens the organ anteroposteriorly and causes a considerable diminution in the area of its posterior surface. In the second instance, the viscus is projected forward, shelf-like, and increases the area of the bed of the stomach; in the first, it is flattened against the posterior abdominal wall (Jackson[96]).

THE LIVER (Figs. 121, 122, 123, 127, 128, 129, 130, 131, 132, 151, 163)

The liver of the full-term newborn child generally weighs between 120 and 150 gm. The average weight in a series of over 100 cases collected by the writer from the literature and from personal observation was 135 gm. All cases of known or suspected lues congenita were omitted from this series. The weight of the liver is more than doubled in the first year and tripled in the third. By the ninth year the liver has increased six times and by puberty nearly 10 times. The total increase in the weight of the liver between birth and maturity is about twelve- or thirteen-fold. The organ forms about 4 per cent. of the body weight at birth, 3 to 4 per cent. during the greater part of childhood and 2.5 to 3 per cent. in the adult. As the liver is, one of the most variable organs in weight in the body, the statements given above are to be regarded as approximations only; and specimens which are apparently normal may be far above or below the given averages.

There are a number of records of the dimensions of the liver in childhood, but most of these are of little value because they are based upon measurements of the fresh specimens removed from the body. Ruge,[21] who studied a few specimens which had been properly hardened in situ, found that the average height was about 8 cm., the average breadth about 11 cm., and the average thickness about 7.5 cm. Thus the height and breadth are about one-half the adult dimensions and the thickness about two-thirds. Although I have made no series of measurements on the newborn I am inclined to think that Ruge's measurements will be found distinctly above the average if an extensive series of specimens is examined.

According to Ruge's studies, the breadth of the liver in the newborn is to its thickness as 1.4 or 1.47 : 1 while in the adult this relation varies from 1.3 : 1 to 1.8 : 1. The relation of breadth to height was as about 1.4 : 1 in the newborn and 0.95 : 1 to 1.2 : 1 in the adult.

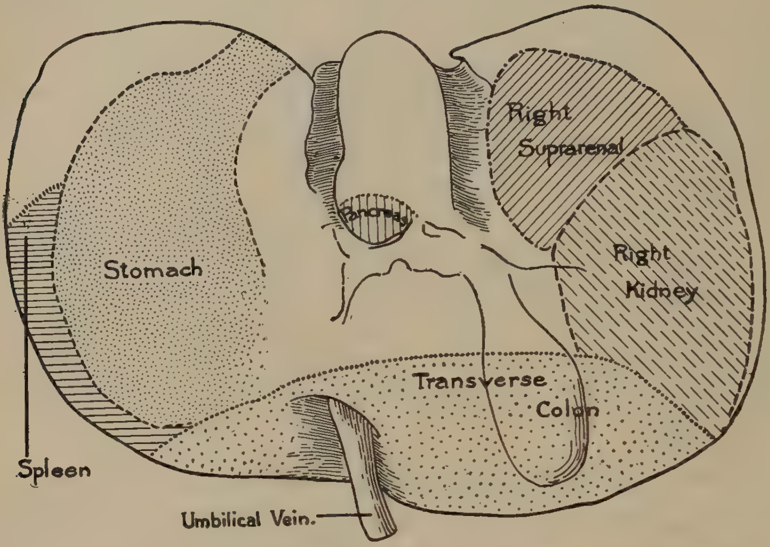

Fig. 127.—An outline of the interior surface of the liver of a newborn child 50 cm. long, showing areas of visceral contact. Natural size.

Several tabulations have been published of the dimensions of the liver in childhood as determined by palpation and percussion. Among the more important are those of Dauchez,[76] and of Frerichs.[88] The latter is quoted below.

Table 14.—The Vertical Diameter of the Liver in Centimeters as Determined by Percussion (After Frerichs[88])

Age	At right axillary line	At right mammary line	At right sternal line
Under 2 years..........	4.5	3.8	2.4
2 to 6 years..........	5.8	4.4	3.7
6 to 10 years..........	7.5	6.8	3.3
10 to 15 years..........	7.1	7.6	4.4
15 to 20 years..........	8.9	8.9	5.9
20 to 40 years..........	9.4	9.5	5.8

Although the left lobe of the liver is somewhat larger relatively in early life than in maturity, this difference has apparently been greatly exaggerated. Kovalski's[120] series of weighings indicate that the left lobe forms a little over one-third of the organ in the newborn and young infant and from one-third to one-fourth in later childhood and adolescence. Probably most of the apparent decrease in the relative size of the left lobe as seen in situ in the abdomen is due to the shifting relations of the organ during early life.

At birth the liver fills about two-fifths of the abdominal cavity. Its anterior surface occupies practically all of the right hypochondriac as well as a considerable portion of the upper umbilical and left hypochondriac region. On the right side its inferior margin lies about 1 to 1.5 cm. above the right iliac crest. From this point it extends upward and to the left, to pass under the left costal arch at the level of the seventh to tenth rib. The inferior margin is slightly convex from above downward and usually lies about 1 cm. above the umbilicus in the mid-line. The upper margin of the liver generally lies at the level of the fifth or sixth rib on the right and the sixth or seventh rib on the left side. According to Ballantyne[1] the anterior surface of the liver in the normal newborn infant corresponds in vertical extent to the last four thoracic and the first two lumbar vertebræ.

The visceral relations of the inferior surface of the liver in the young infant are illustrated in Figs. 127, 156. The lower surface of the left lobe is in contact with the spleen, stomach, lower part of the esophagus, a small portion of the transverse colon, and sometimes a little of the left suprarenal. The right lobe is in contact with the right kidney and suprarenal, and a large part of the transverse colon. The pancreas comes in contact with the papillary process of the caudate lobe, and the duodenum touches the posterior margin of the quadrate lobe or the porta. The areas of contact of the stomach and transverse colon vary greatly with the distension and contraction of these structures. Sometimes, when the colon is considerably contracted, the small intestines come in contact with a large part of the lower surface of the right lobe. In cases of incompletely descended cecum both this structure and the ascending colon form distinct impressions on the inferior surface of the liver.

Accurate studies, by modern anatomical methods, of the topography of the liver in later childhood are practically lacking because of the great difficulty in securing normal and well preserved material. The reconstructions of Symington which are reproduced in Figs. 122, and 123 give some idea of the position of the viscus in the middle years of childhood but the liver in the older individual (Fig. 123) is distinctly enlarged. Studies of the topography of the liver by means of percussion and palpation have generally shown that the anterior surface of the organ is gradually covered more and more by the diaphragm and costal arches, and that the anterior surface of the left lobe becomes relatively much smaller. However Cruchet and Sérége,[74] examining 160 cases, found that the inferior margin of the right lobe rapidly approaches the right costal margin until the second year when it again begins to descend until about the middle of the second period of childhood. After this time, a second period of ascent occurs ending in adolescence with the right liver margin at the usual normal adult position. These authors found much more variation in the topography of the right lobe than the left lobe of the liver. The descent of the right margin after the first year is possibly due in part to the change from a milk to a mixed diet, which has been shown to increase the volume of the liver, and in part to the effect of gravity after the erect posture becomes habitual. Figures 130, 131 show the results of these authors in graphic form.

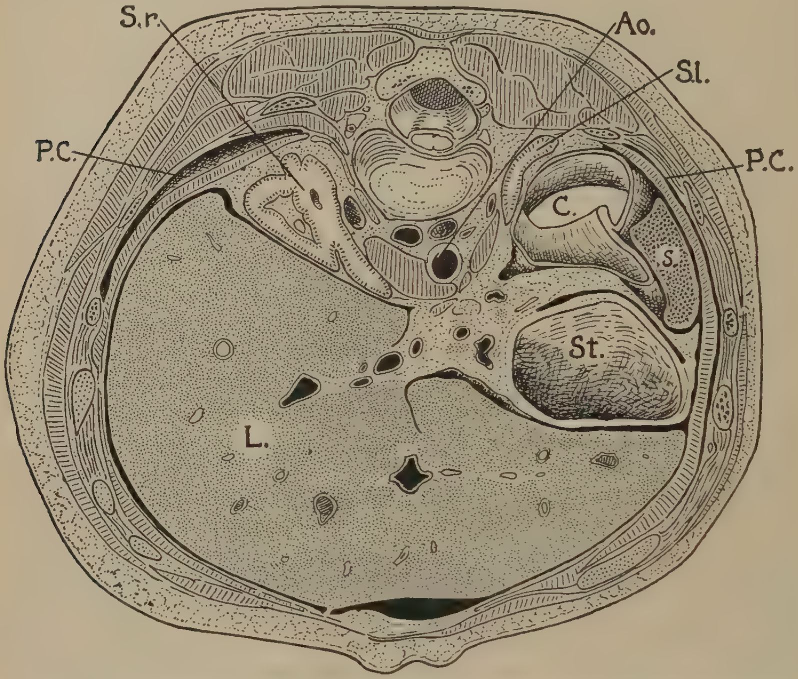

FIG. 128.—A transverse section through the upper portion of the abdomen of a full-term newborn child. Ao., aorta; C., splenic flexure of colon; L., liver; P.C., pleura cavity; S.l., left suprarenal; S.r., right suprarenal; S., spleen; St., stomach. Natural size.

The changes in the relation of the liver to the stomach and spleen are discussed in connection with these organs.

The lobular structure of the liver is not striking in the newborn or in the first few months of post-natal life, although vascular areas which will later be mapped off into permanent lobules can be distinguished. According to the observations of Kovalski,[103] the definite mapping out of the lobules takes place toward the end of the first year and the adult appearance is not acquired until after the first period of childhood. In early infancy the hepatic trabeculæ are arranged in a wide meshed network and their final radial position is only acquired as the definite lobulation of the hepatic parenchyma takes place. There seems to be some reduction in the average number of cells surrounding the bile capillaries after birth, although this change is apparently a very irregular one. According to the measurements of Toldt and Zuckerkandl,[130] the average dimensions of the liver cells are almost doubled between birth and maturity but the average size of the nuclei is slightly reduced. Cells containing two nuclei are found at birth and in early life as in maturity. Fat droplets of considerable size are found in the hepatic cells in later fetal life and at birth. Pigment granules are also present in the newborn but are not as prominent as in later life. Clusters of developing blood-corpuscles are still found in the liver at birth but disappear very shortly thereafter.

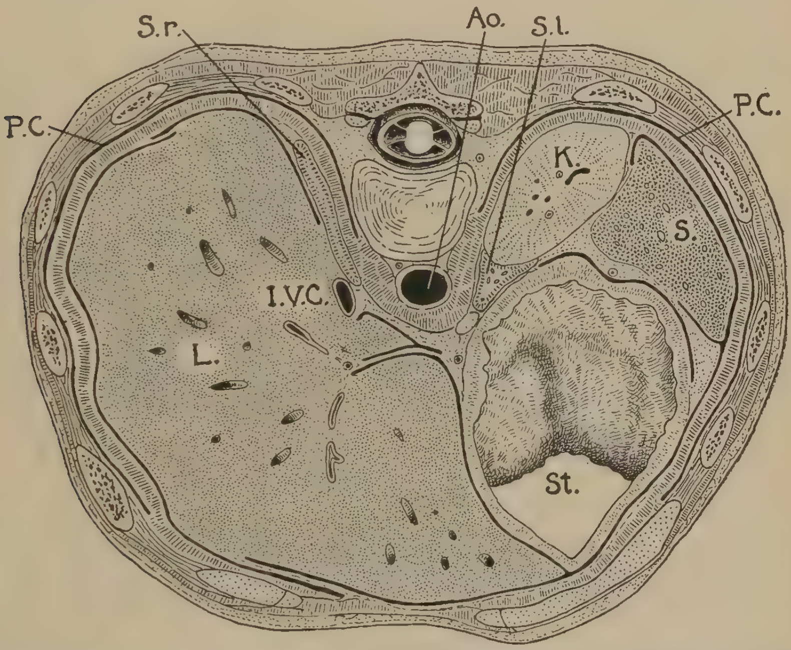

Fig. 129.—A transverse section of the upper portion of the abdomen of a girl 3 years old. Ao., aorta; I.V.C., inferior vena cava; K., left kidney; L., liver; P.C., pleural cavity; S.l., left suprarenal; S., spleen; S.r., right suprarenal; St., stomach. Two-thirds natural size. (After Dwight.[4])

At birth, hepatic parenchyma extends into the left portion of the coronary ligament and sometimes into the falciform ligament as well. This portion of the liver substance undergoes involution, probably as the result of pressure. Some remoulding of the liver, through the involution of certain parts, probably takes place after birth but the greater part of this process undoubtedly is accomplished in later fetal life. As has been remarked, the concept of a pronounced degeneration of the left lobe in post-natal life is not supported by the observations of Kovalski.

The gall-bladder of the young infant is relatively small. It is usually more embedded in the liver substance than in later life and has a proportionately smaller peritoneal surface. At this time the sac may be crossed by bands of hepatic substance which in many cases undergo involution in later life. Often the fundus does not extend to the margin of the liver at birth. Geptner (quoted by Gundobin) found that the capacity of the gall bladder increased very rapidly in the first two years during which time it acquired the same relative size, in comparison to the liver weight as in the adult. Thereafter the increase in liver weight and gall-bladder capacity is proportional.

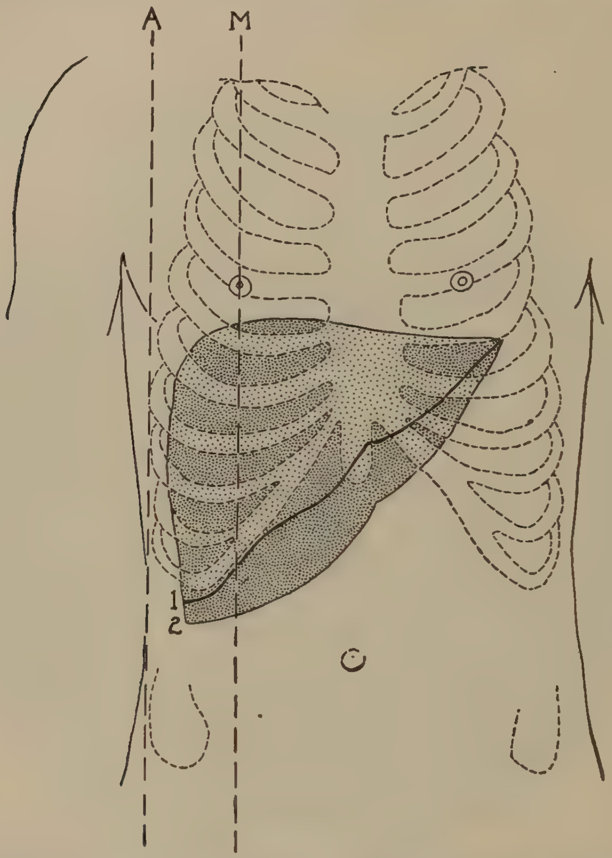

FIG. 130.—A diagram illustrating the position of the liver in childhood as determined by percussion: 1, position of liver in second year; 2, position of liver in later childhood. A, axillary line. B, mammary line. (After Cruchet and Sérége.[74])

THE RESPIRATORY SYSTEM

THE NOSE AND PARANASAL SINUSES (Figs. 107, 133, 135, 137)

An even moderately full discussion of the post-natal development of the nose and paranasal sinuses would require an amount of space and illustration which is not available in a summary like the present one. I shall therefore limit my description to a bare outline of the subject, referring the reader to the accounts of Disse,[144] Davis,[143] Killian,[149] Onodi,[155] Schaeffer[159, 160, 161] and Torrigiani[163] for detailed information.

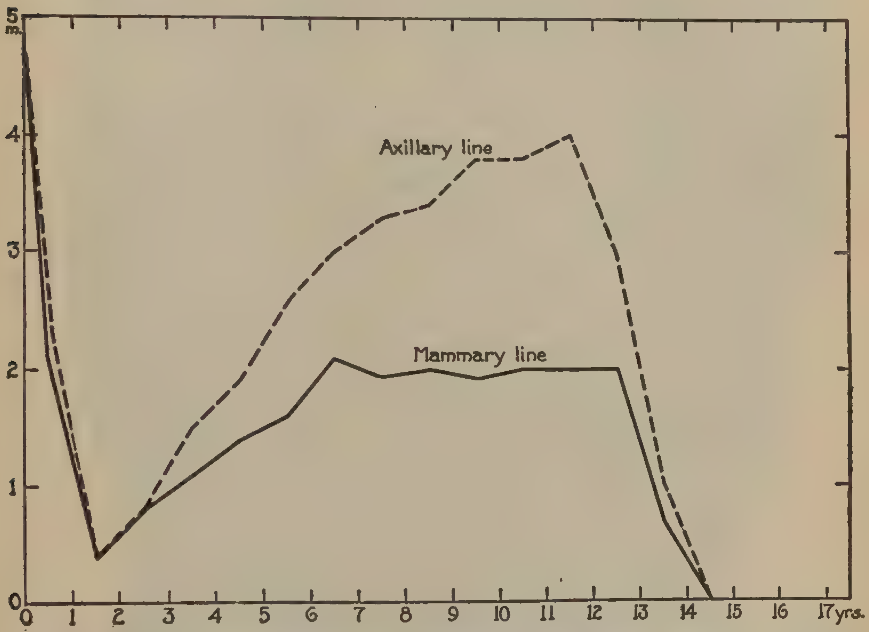

FIG. 131.—A graph showing the distance of the inferior margin of the liver below the right costal margin at different periods in childhood. (After Cruchet and Sérége.[74])

The nasal cavities of the newborn are low, broad, and relatively long. The height of the cavity, according to the measurements of Disse and Feldberg (quoted by Gundobin[7]) is 18 to 19 mm. This height increases nearly one-half in the first year but grows much slower thereafter. At seven years it is about double and in maturity from two and one-half to three times that of the infant at birth. The length or anteroposterior diameter of the nasal cavity is difficult to measure accurately. Judging from measurements of the hard palate at the median line it is doubled in the first seven years and after this time grows very little. The transverse diameter of the cavity measured at its base is about 7 mm. in the newborn, it increases very slowly to about 9.5 mm. in the first five years, and is about doubled by maturity. The nasal cavity may be divided into ethmoid and maxillary

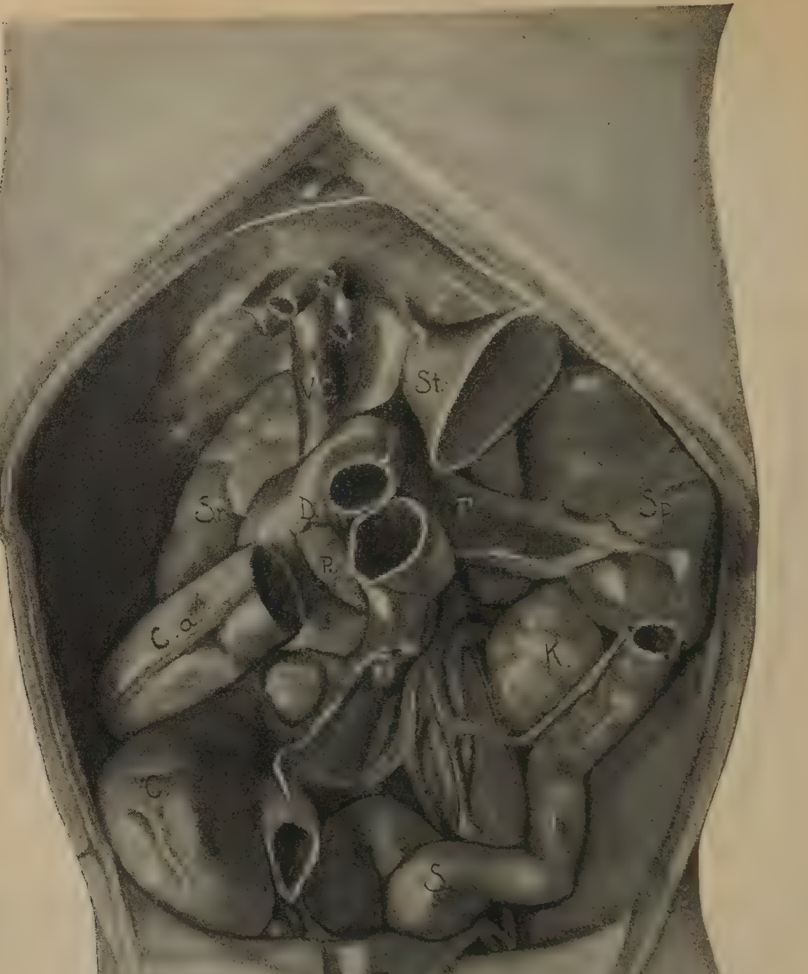

Fig. 132.—Dissection of the posterior abdominal wall of a newborn child that had lived about ten hours. The liver, the greater part of the small intestine, the transverse colon and the greater part of the stomach have been removed. B., bladder; C., cecum; C.a., ascending colon; D., duodenum; K., kidney; P., pancreas; S., sigmoid colon; Sp., spleen (somewhat enlarged); S.r., right suprarenal; St., cardiac end of stomach; U.A., umbilical arteries; U.V., umbilical vein; V.C., vena cava inferior. Natural size.

portions corresponding respectively to the parts bounded by these bones. The ethmoid part forms approximately two-thirds of the nose at birth. During the first year the maxillæ grow very rapidly and from the second year on the two portions are about equal in height.

The nasal conchæ are all differentiated during fetal life and the upper ones, the conchæ suprema I, II and III of Schaeffer, are often better marked in the fetus and newborn than in the adult. For the details regarding their form and divisions the reader is referred to the work of Schaeffer and of Davis, and for statistics regarding their post-natal growth to Disse and to Feldberg. The lower margin of the inferior concha is frequently in contact with the floor of the nasal cavity at birth, and a functional inferior nasal meatus can hardly be said to exist during the first year or two of post-natal life. The nasal septum is long anteroposteriorly and low vertically in the young infant. At this time it is composed almost entirely of cartilage. The septum is straight at the time of birth and for several years thereafter. Its frequent deviation in later life has been explained both on the basis of its rapid growth (as compared with the lateral walls of the nasal cavity) and also on the basis of the irregular eruption of the median incisor teeth (Mosher[153]). Small parallel ridges representing septal concha are sometimes found on the septa of newborn children.

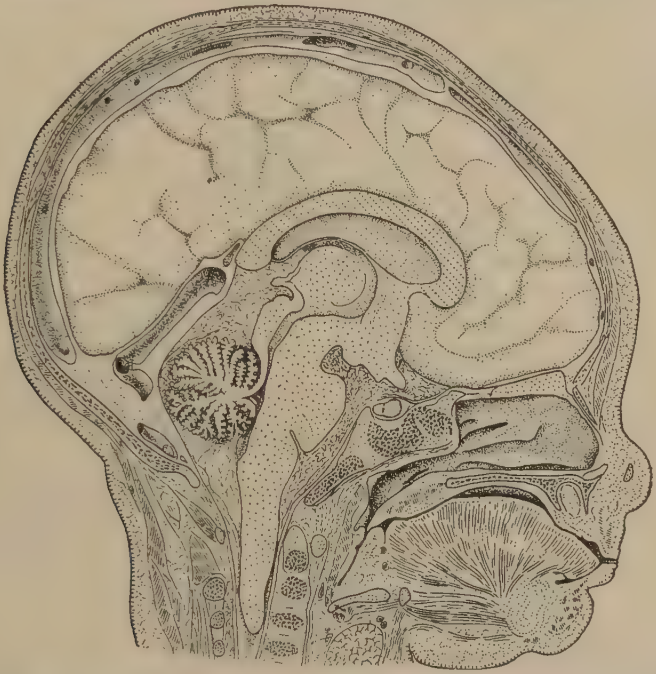

Fig. 133.—A median sagittal section of the head of a full-term, newborn child. Natural size. Figure 134 is an outline drawing of a part of the same section identifying the principal structures.

The height and breadth of the posterior nares or choanæ are about equal at the time of birth (5 to 7 mm.). According to Disse, these openings double in size in the first six months, remain stationary until the end of the second year, and then enter on a second period of rapid growth. The height of the openings increases much more rapidly than the breadth and the ratio between height and breadth, which is about 1:1 at birth, is about 3:2 at three years and 2:1 in the adult.

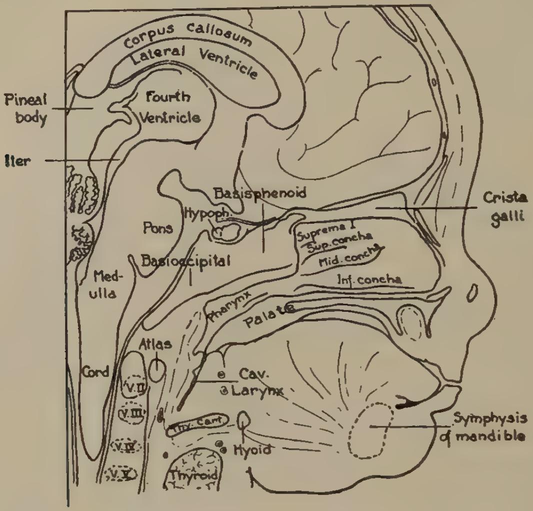

FIG. 134.—An outline drawing of a portion of the section shown in Fig. 133 with identifications of the chief structures.

THE MAXILLARY SINUS

The maxillary sinus, or antrum of Highmore, arises in the third month of fetal life as a small outpouching from the lateral wall of the ethmoidal infundibulum. The neck of the pouch remains small and forms the ostium maxillare while the distal portion enlarges to form the sinus proper. The form of the sinus is dependent on that of the maxilla which it soon invades. At birth it is a cavity from 8 to 10 mm. in length anteroposteriorly and 3 to 5 mm. in diameter transversely and vertically. The growth of the sinus in post-natal life proceeds parri passu with that of the body of the maxilla. According to Davis, its anteroposterior diameter increases about 3 mm. per year and the vertical and transverse diameters about 2 mm. per year until the eighth year of life. After the eighth year the growth of the sinus is slower in all directions until the fifteenth to the eighteenth year when the adult type is approximately reached. While the sinus is almost tubular in the newborn and young infant it is more or less ovoid in the earlier part of childhood; its pyramidal form is acquired after the erruption of the permanent dentation. At birth the floor of the maxillary sinus lies distinctly above that of the nasal cavity. It descends slowly during the greater part of childhood. Table 15 is a summary of the extensive series of measurements of the sinus published by Davis.

TABLE 15.—THE GROWTH OF THE RIGHT MAXILLARY SINUS
(Summarized from the Tables of Davis[143])

Age	Number of cases	Diameters in millimeters		
		Vertical	Transverse	Antero-posterior
8 days to 1 yr	10	5.4	4.7	13.4
1 to 3 yrs	18	8.6	7.2	18.9
3 to 6 yrs	17	12.2	11.9	24.7
6 to 9 yrs	18	19.0	16.4	28.4
9 to 12 yrs	5	20.5	17.4	28.7
12 to 15 yrs	5	22.7	17.1	24.9

THE SPHENOIDAL SINUS

The sphenoidal sinus arises in the early part of the third fetal month from the upper and posterior part of the spheno-ethmoidal recess. The sinus is well marked although minute at birth. It grows rather slowly during the first four or five years of life. After the fifth year its growth is much more rapid and its adult dimensions are attained early in adolescence. Davis has pointed out that at first the sinuses grow faster posteriorly and laterally than they do medially. As a result the septum separating them is much thicker in the infant than in older children or adults.

TABLE 16.—THE GROWTH OF THE RIGHT SPHENOIDAL SINUS
(Summarized from the Tables of Davis[143])

Age	Number of cases	Diameters in millimeters			Thickness of septum, millimeters
		Vertical	Transverse	Antero-posterior	
8 days to 1 yr	10	2.8	2.0	1.6	7.0
1 to 3 yrs	18	4.8	3.7	2.3	7.3
3 to 6 yrs	17	6.3	5.2	4.1	6.1
6 to 9 yrs	18	11.9	8.9	9.1	3.3
9 to 12 yrs	5	11.4	11.3	10.8	1.2
12 to 15 yrs	5	15.3	13.1	13.1	2.9

THE FRONTAL SINUS

The frontal sinus arises from the anterior and superior extension of the middle nasal meatus which is known as the frontal recess. The frontal recess can be found as early as the end of the third or the beginning of the fourth fetal month but the definitive frontal sinus is only occasionally recognizable at birth, and may not be present until the second or the third year of post-natal life. The exact method of origin of the sinus varies in different individuals. It may arise as an extension of the entire frontal recess; from one of the anterior ethmoidal cells; or, rarely, from the ethmoidal infundibulum (Killian,[149] Schaeffer[161]). Many of the variations in the adult sinus can be explained upon the basis of this variation in its method of origin. The post-natal growth of the sinus is illustrated by the summary of Davis' table quoted below. The sinus generally begins its invasion of the vertical portion of the frontal bone in the second year; and from two to six years its superior margin lies 1.5 to 5 mm. above the nasion. Its

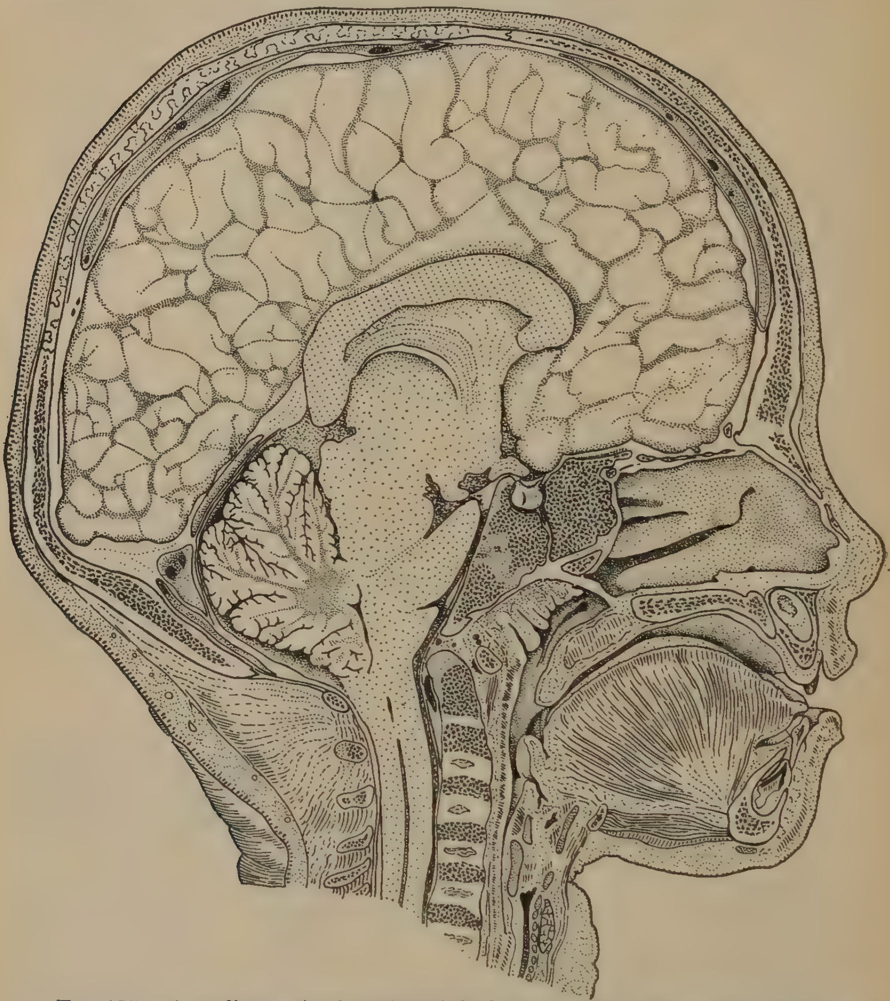

FIG. 135.—A median sagittal section of the head of a boy five years old. Three-fifths natural size. Fig. 136 is an outline drawing of a part of same section identifying the principal structures. The persistent basi-pharyngeal canal seen in this specimen is an unusual anomaly.

ascent is more rapid after this time but the adult position of the superior margin (about 25 mm. above the nasion) is not generally acquired before the sixteenth year. Davis found the average thickness of the anterior bony wall of the sinus in the first year to be 4 mm., and of the posterior 2 mm.; but as the sinus expands the bone surrounding it is resorbed so that these measurements are usually reduced about one-half by maturity.

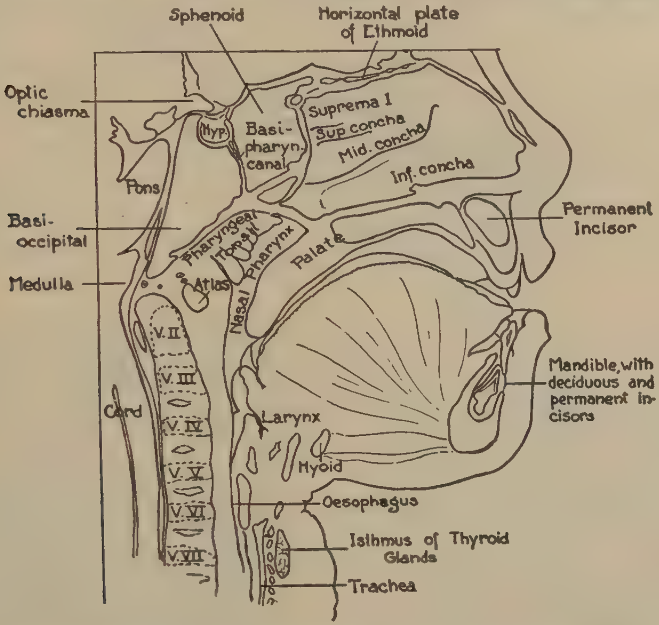

FIG. 136.—An outline drawing of a portion of the section shown in Fig. 135 with identifications of the chief structures.

TABLE 17.—THE GROWTH OF THE RIGHT FRONTAL SINUS
(Summarized from the Tables of Davis[143])

Age	Number of cases	Diameters of sinus in millimeters			Thickness of anterior wall, millimeters	Thickness of septum, millimeters
		Vertical	Transverse	Antero-posterior		
8 days to 1 yr. . .	10	2.7	1.6	3.3	4.0	9.6
1 to 3 yrs.	18	5.3	3.0	4.7	3.7	9.8
3 to 6 yrs.	17	6.8	4.1	6.0	4.4	8.7
6 to 9 yrs.	18	10.0	6.3	8.6	3.1	4.8
9 to 12 yrs.	5	11.2	8.5	7.8	3.1	5.5
12 to 15 yrs.	5	13.9	17.1	12.2	3.1	2.4

THE ETHMOIDAL SINUSES

The ethmoidal sinuses arise from grooves and recesses in the lateral walls of the middle and superior nasal meati. These invaginations are formed in the latter part of the third and the fourth fetal month and definite cells are present by the sixth fetal month. For their later development, which is extremely variable, I must again refer the reader to the studies of Davis and of Schaeffer.

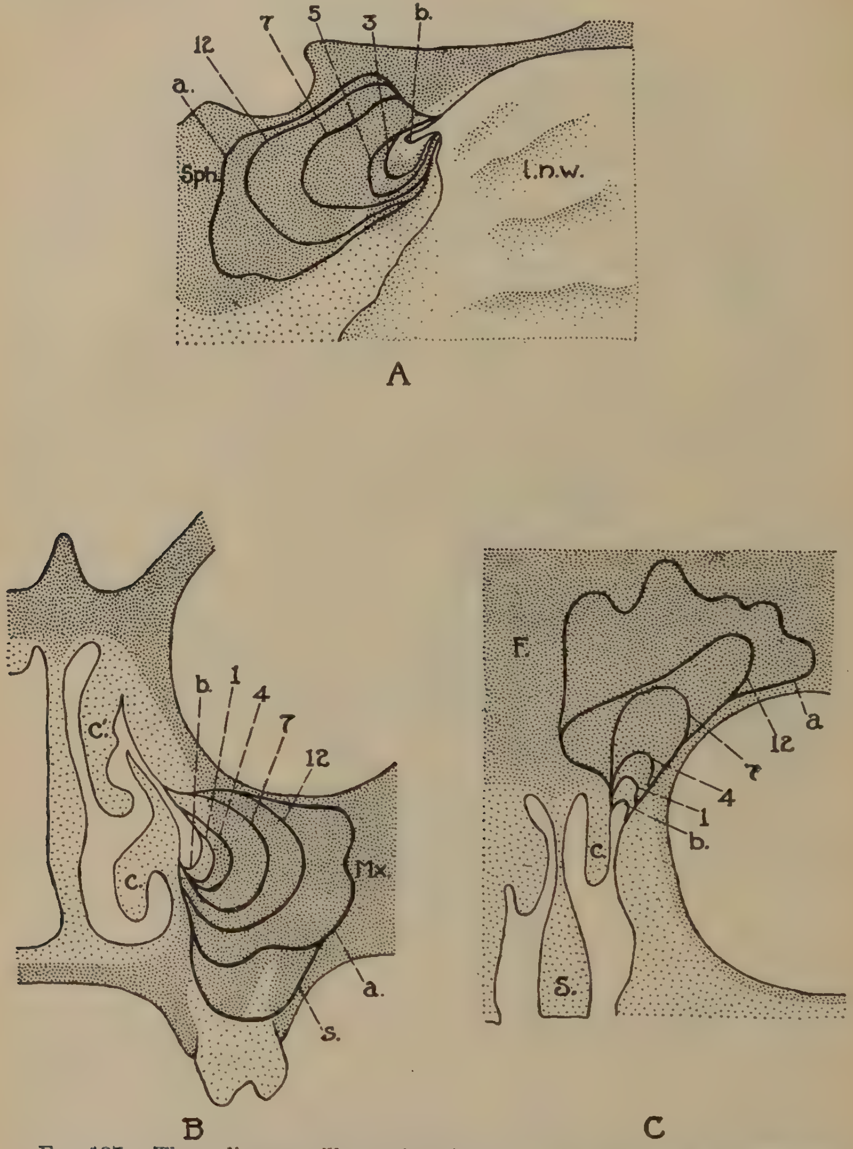

Fig. 137.—Three diagrams illustrating the post-natal growth of the paranasal sinuses. A., sphenoidal sinus; B., maxillary sinus; C., frontal sinus. c.–c′., conchæ; F., frontal bone; l.n.w., lateral nasal wall; Mx., maxilla; S., nasal septum; Sph., body of sphenoid bone. Solid black lines indicate the extent of the sinus at different ages. The Arabic numerals indicate age in years; "b" indicates birth; "a," maturity; "s," senility. (After Torrigiani.[163])

THE LARYNX (Figs. 133, 135, 138, 139)

The larynx of the newborn is approximately 2 cm. in length. Its maximum breadth, at the upper margin of the thyroid cartilage, is almost equal to its length. The absolute dimensions of the larynx at birth are approximately one-third those of the adult but relatively it is as large if not larger than in maturity.

The external form of the larynx is more rounded in infancy than in later life. The thyroid cartilage is broader and shorter and lies almost in contact with the hyoid bone above. The lateral lamina of the thyroid cartilage meet at an obtuse angle and neither the laryngeal prominence (Adam's apple) nor the superior thyroid notch are as marked as in later life. The cricoid cartilage has much the same form as in adult life but it is tilted downward and backward so that it forms an oblique angle with the thyroid cartilage above.

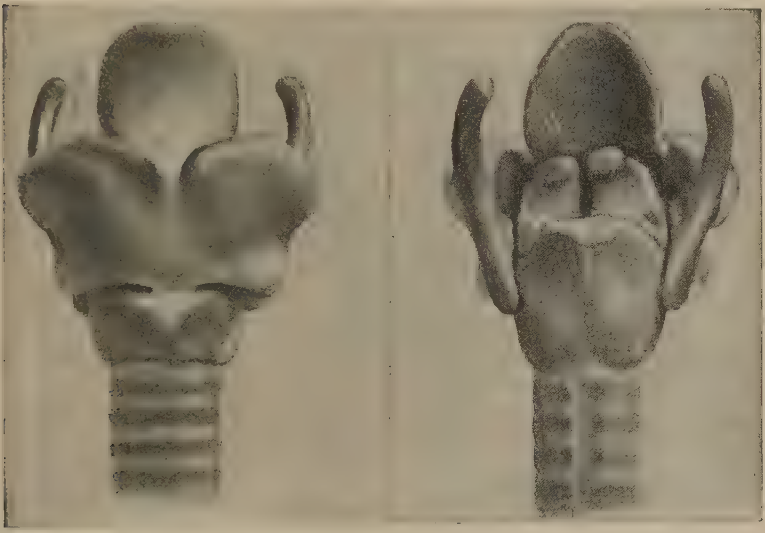

FIG. 138.—Anterior and posterior views of the larynx of a full-term, newborn male child 52 cm. long. Twice natural size.

The cavity of the larynx is short and funnel-shaped in the infant. These characters are particularly marked in the upper segment or vestibule. The true vocal cords are from 4 to 4.5 mm. in length and are relatively shorter than in later childhood and in the adult. The ventricle of the larynx is small but the ventricular appendix or saccule of Morgagni is often of considerable size. The inferior laryngeal cavity or subglottic space extends backward as well as downward in the suckling, whereas it is almost vertical in older children and in the adult. This inclination of the axis of the lower part of the laryngeal cavity is a point of some importance in connection with the procedure of intubation in the young infant.

The post-natal growth of the larynx may be divided roughly into three periods: first, from birth to two or three years, a period of rapid general growth; second, from two or three years to puberty, during which time growth proceeds rather slowly although a number of alterations in form take place; and third, the period of puberty in which growth takes place rapidly, particularly in males. At the end of the third year of life the larynx has increased approximately one-half in length and circumference, and by the time of puberty these dimensions are about double those of the newborn. During the period of puberty there is again an increase of approximately 50 per cent. in all dimensions.

Sexual differences in the larynx appear about the third year. After this time the larynx is longer and larger in boys than in girls and the angle between the lateral plates of the thyroid cartilages becomes more pronounced. These differences are accentuated during childhood and particularly during puberty when the male larynx grows much more throughout than does the female.

The larynx gradually descends in the neck during both fetal and post-natal life. According to the observations of Symington[14] and Berkenbusch,[2] the upper end of the epiglottis lies at the level of the first cervical vertebra in the newborn; at six years it is opposite the lower margin of the first or the body of the second cervical vertebra; and at puberty it is opposite the lower part of the third cervical vertebra. In the adult it lies at the level of the lower part of the third or upper part of the fourth cervical vertebra. The lower border of the cricoid cartilage lies at the level of the fourth cervical vertebra at birth; it descends to the level of the fifth or sixth by six years; and to the level of the seventh by puberty. All of these measurements were made with the head erect.

THE TRACHEA (Figs. 139, 140, 177)

The average length of the trachea in the full-term newborn is approximately 4 cm. The length in the adult is about three times that of the newborn. As in the adult, the child's trachea is broader above than below, and the frontal diameter of its cavity is slightly greater than its sagittal diameter. Both diameters increase about 300 per cent. between birth and puberty. Details of the growth of the trachea in length and caliber will be found in the following table. In this table the length of the trachea is measured from the inferior border of the cricoid cartilage to the bifurcation; and the diameters are measured in the middle third of the tube. A portion of the latter are taken from wax or metal casts; but measurements made in this way agree well with those made from the tube in cross-section.

The walls of the trachea are relatively thick at the time of birth, and the total number of tracheal cartilages are present at a comparatively early stage of fetal life. The tracheal cartilages and the annular ligaments separating them grow at the same rate during childhood. After puberty the increase in length of the trachea is apparently brought about mainly through the increasing breadth of the annular ligaments. In the child, as in the adult, the posterior membranous wall of the trachea forms about one-sixth of the circumference of the tube. The muscular layer of the membranous wall is extremely variable in thickness at all ages and is often as thick in the newborn as it is in the adult at maturity. The subepithelial and more peripheral elastic tissue layers are present at the time of birth but are comparatively weakly developed. There is a great increase in the tracheal elastic tissue during the first two years of life. The majority of the tracheal glands are present at the time of birth although possibly some are formed after that time. They do not attain their complete function until some time after birth.

Table 18.—The Dimensions of the Trachea in Childhood

(Based upon the Data of Engle, Gegovd, Koike, Mettenheimer, Oppikofer, Passavant, and Scammon)

Age	Length of trachea		Diameter of tracheal lumen		
	Number of cases	Average length, centimeters	Number of cases	Sagittal, millimeters	Frontal, millimeters
0 to 1 mo.	20	4.0	11	3.6	5.0
1 to 3 mos	30	3.8	35	4.6	6.1
3 to 6 mos	35	4.2	37	5.0	5.8
6 to 12 mos	23	4.3	25	5.6	6.2
1 to 2 yrs	17	4.5	18	6.5	7.6
2 to 3 yrs	19	5.0	22	7.0	8.8
3 to 4 yrs	12	5.3	12	8.3	9.4
4 to 6 yrs	22	5.4	25	8.0	9.2
6 to 8 yrs	14	5.7	16	9.2	10.0
8 to 10 yrs	14	6.3	16	9.0	10.1
10 to 12 yrs	8	6.3	10	9.8	11.3
12 to 14 yrs	5	6.4	6	10.3	11.1
14 to 16 yrs	9	7.2	10	12.7	14.0
Adult	..	12 (9–15)	..	17.2(13–23)	14.7 (12–18)

The compressibility of the trachea, *i.e.*, the ability of the tube to resist external pressure, is very low in the newborn. It is about one-third that of a year old child, one-fourth that of a five year old and one-sixth that of an adult. The elasticity of the trachea in childhood, after the suckling period, is considerable; but it decreases after puberty. The extensibility of the trachea is relatively the same in childhood and maturity.

The upper limit of the trachea in the newborn and suckling lies at the level of the fourth cervical vertebra when the head is held erect. Complete extension raises it about one vertebral level, while acute flexion depresses it an equal degree. The upper limit of the trachea descends during childhood, at first rapidly and then more slowly, to reach the average adult position of the seventh cervical vertebra. There is considerable variation in the rate and degree of descent during the latter part of childhood.

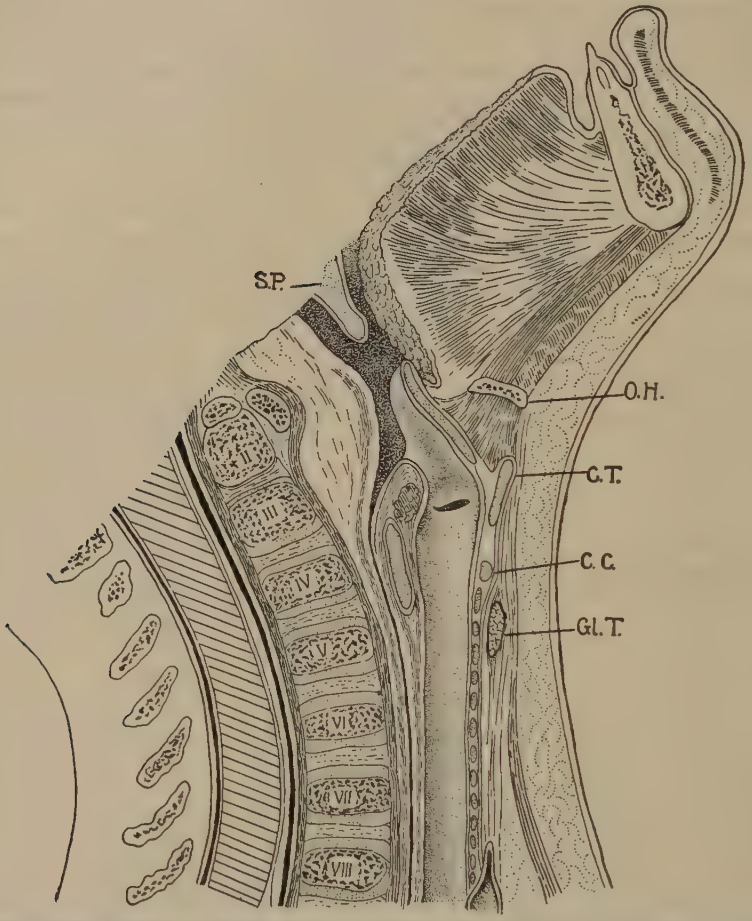

FIG. 139.—Median sagittal section of the neck of a boy two years and nine months old, with the head in extreme extension. C.C., cricoid cartilage; C.T., thyroid cartilage; Gl. T., thyroid gland; O.H., hyoid bone; S.P., soft palate. (After Passavant.[154])

The bifurcation of the trachea in the newborn lies at the level of the third or fourth thoracic vertebra. It descends very slowly the first few months but later proceeds more rapidly. The following table of the position of the bifurcation is based upon Engle's[145] radiographic studies to which the reader is referred for further details.

TABLE 19.—POSITION OF THE BIFURCATION OF THE TRACHEA IN CHILDHOOD AS DETERMINED BY THE ROENTGEN-RAY
(AFTER ENGLE)

Age	Position
0 to 2 yrs.	Lower margin of IIIrd to lower margin of IVth T. V.*
3 yrs	Middle margin of IVth to upper margin of Vth T. V.
4 yrs	Middle margin of IVth to lower margin of Vth T. V.
5 yrs	Lower margin of IVth to lower margin of Vth T. V.
9 yrs	Upper margin of Vth to middle margin of VIth T. V.
12 yrs	Middle margin of Vth to middle margin of VIth T. V.

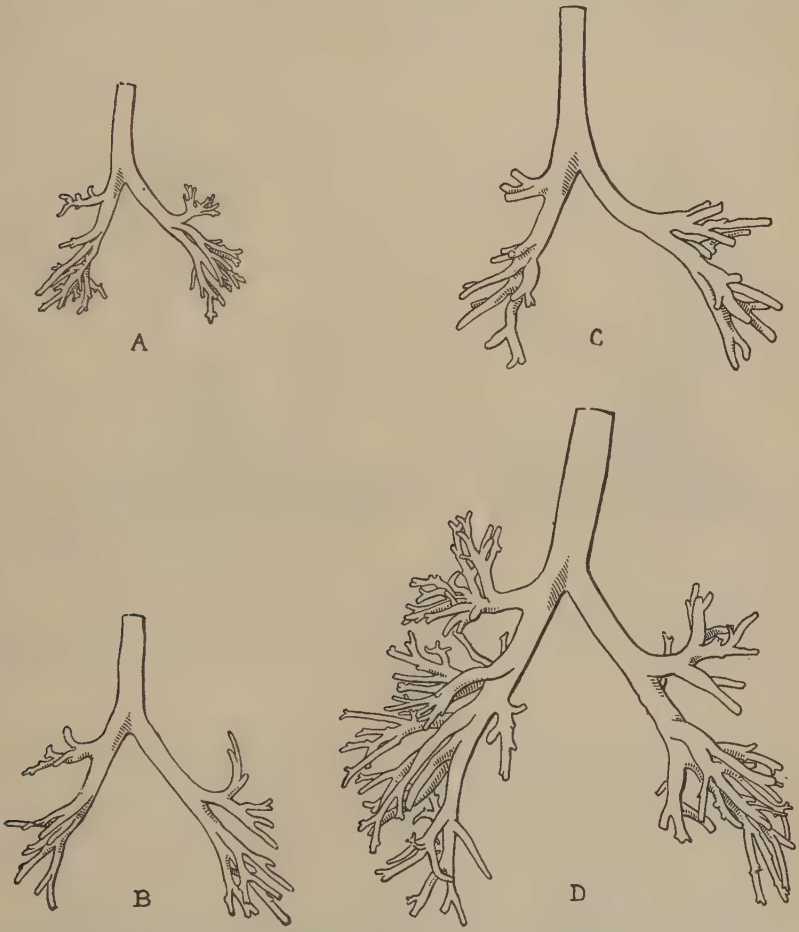

FIG. 140.—Four outline drawings of casts of the bronchial trees of children. A, child of three months; B, child of one year; C, child of three years; D, child of seven years. One-half natural size. (After Engel.[146])

*T. V., Thoracic vertebra.

The relation of the trachea to the sternum undergoes considerable change during childhood. The length of the cervical portion of the trachea (from the upper margin of the sternum to the lower margin of the cricoid cartilage) is, according to Passivant,[154] 3.6 cm. in the newborn with head erect and 4.0 cm. with the head extended. These distances increase to 7.5 cm. and 10 cm. respectively in children of 9 to 18 months.

THE LUNGS (Figs. 122, 123, 141, 142, 164, 167, 178)

The weight of the lungs in the newborn, as at all times of life, is extremely variable. The average weight in the full-term child at birth is about 50 gm. Theoretically, it might be expected that the lungs of children in which respiration had been established would be relatively heavier than those of stillborn infants, because of the influx of blood into the lungs through the expanding pulmonary arteries. As the difference in the ratio of lung to body weight in stillborn and live-born children was at one time advanced as a practical test in cases of suspected infanticide, careful and extensive studies have been made on this point. These studies have shown that if any such difference exists it is so small that it is masked in any extensive series of cases by the natural variability of the weight of the organs. The lungs increase to twice their birth-weight or more in the first six months of post-natal life and often triple their weight in the first year. The rate of weight increase of the lungs is practically the same as that of the body as a

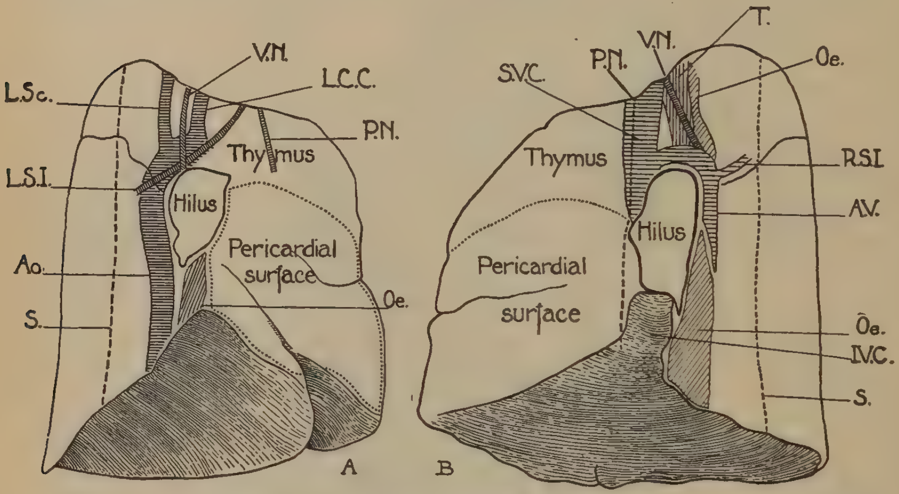

FIG. 141.—Outlines of the medial surfaces of the lungs of a newborn child showing the visceral relations. A, left lung; B, right lung. Ao., aorta; A.V., azygos vein; I.V.C., inferior vena cava; L.C.C., left common carotid artery; L.Sc., left subclavian artery; L.S.I., left superior intercostal vein; Oe., esophagus; P.N., phrenic nerve; R.S.I., right superior intercostal vein; S., line of vertebral column; S.V.C., superior vena cava; T., trachea; V.N., vagus nerve. (After Huntington.[9])

whole during the entire period before maturity. The absolute weight of the lungs in the adult is approximately 20 times that of the newborn; and the relative weight remains fairly constant throughout postnatal life.

The volume of the lungs in the newborn infant, with respiration established, was found by Aeby to be 67 c.c. The increase in lung volume like that in lung weight, keeps pace with the increment in body weight. The right lung is larger than the left from the time of formation of the lung buds in the embryo. Jackson found it to be 25 to 30 per cent. larger in the newborn, a greater difference than is generally quoted for the adult.

In the full-term stillborn infant the lungs do not fill the entire potential pleural cavity. They are in close contact with the posterior half of the mediastinum and the costal pleural surfaces; but generally they are not pressed against the anterior chest wall, and they never extend into the costo-phrenic sinus. The anterior medial borders do not extend so far towards the mid-line of the body as they do in the infant whose respiration is fully established, and the left lung is indented by a very extensive cardiac notch which often occupies fully half of its medial border. As a result of this position, the lungs of the stillborn infant are short, broad, and thin, as compared with those of the child in which respiration has been established; and while the impressions of the structures bounding their posterior parts are well marked, their anterior surfaces are often smooth except for the deep cardiac notch mentioned above. The anterior, inferior, and medial margins of the lungs are much sharper in the stillborn than in the liveborn and the inferior surfaces are much more convex because of the greater arching of the diaphragm.

With the establishment of respiration and the consequent expansion of the lungs, the shape and position of these structures is greatly changed. They increase in all diameters, but particularly in the sagittal one, along with the descent of the diaphragm. The margin of the left lung surrounding the cardiac notch gradually pushes medially between the pericardium and the sternum so that the so-called bare area of the heart is diminished. At the same time the apex of the heart is shifted downwards and to the right (probably in part through the pressure of the expanding lung) and this change in its position aids in decreasing the extent of the cardiac notch. The anterior, medial, and inferior margins of the lungs lose their sharp margins through the expansion of the peripheral alveoli of these regions. The costo-phrenic sinus, however, is not invaded by the lower lung margins to any great extent at the time of birth, this change occurring as a rule in later childhood.

As respiration is established the skeletal relations of the lungs are also somewhat modified. In the stillborn, according to Mettenheimer,[12] the summits of the lungs lie 3 to 5 mm. above the level of the superior margin of the sternum; and their bases generally at the level of the ninth or tenth rib posteriorly. After respiration the apices lie 5 to 8 mm. above the level of the superior margin of the sternum and the inferior margins lie at the eleventh rib posteriorly.

There is very little change in the skeletal relations of the lungs between infancy and maturity. The inferior margins remain fixed at the eleventh or twelfth vertebra posteriorly; but in the mammillary line there is a slow descent of the lung margin from the level of the fifth rib in the young child to the sixth rib in the young adult.

The topography of the fissures and lobes of the lungs in infancy has recently been studied in detail by Gittings, Fetterolf and Mitchell;[148] they find that the relations of the structures to the bony thorax are practically the same as in the adult.

According to Kolliker the formation of the alveoli of the lungs begins in the sixth fetal month. The number of alveoli increases rapidly until the time of birth but there is little increase in their size. The changes in the alveoli at birth have been recently reinvestigated by Addison and Howe[141] and by Ridella.[157] With the first inspiration the alveoli are enlarged and the epithelium lining them is reduced from a low columnar or cuboidal to an extremely flattened squamous type. The nuclei of the lining cells are flattened and are farther separated from one another. According to Ridella the flattening process begins at the fundus of the air-cell and extends around it from this point to the neck. As the lungs expand the fluid which occupied the trachea before respiration is drawn down into the air-cells and is distributed on the inner surface of their walls. In sections this is seen as a granular precipitate, and large mononuclear cells, possibly phagocytic in function, are found within it. The fluid is absorbed in a short time.

The expansion of the lung at birth is extremely irregular. One may find expanded and unexpanded alveoli in the same lobule; and again lobules made up of expanded alveoli may be scattered among those which show no evidences of expansion. Champneys,[142] who made a special study of this matter in connection with his researches upon the efficacy of various methods of initiating respiration, came to the following conclusions concerning the expansion of the lungs in newborn children.

1. "The right lung is usually better expanded than the left.
2. "The anterior surfaces are usually better expanded than the posterior.
3. "The lower lobes are the parts most often unexpanded.
4. "The right middle lobe is usually well expanded.
5. "The part of the left lung corresponding to the right middle lobe is often better expanded than the rest of the left lung; when the right middle lobe is ill expanded, the corresponding part of the left lung is often unexpanded also."

The production of alveoli ceases at birth except for the formation of a very small number from the walls of the respiratory bronchioles. Thus the greater part of the post-natal increase in volume of the lungs is brought about by the growth of the alveoli which are formed in fetal life. The observations of Rossignol,[158] which are quoted in Table 20 below, are the only extensive ones on the growth of the alveoli. They are based upon measurements of lungs which were inflated and dried, and a considerable degree of error may have been introduced by this procedure.

Table 20.—The Growth of the Respiratory Alveoli (After Rossignol[158])

Age	Average diameter of alveoli
Children who had breathed only a few hours	0.05 mm.
Children of 1 to 1½ yrs	0.10 mm.
Children of 3 to 4 yrs	0.12 mm.
Children of 5 to 6 yrs	0.14 mm.
Children of 10 to 15 yrs	0.17 mm.
Adults of 18 to 20 yrs	0.20 mm.
Adults of 25 to 40 yrs	0.20 to 0.25 mm.
Adults of 50 to 60 yrs	0.30 mm.
Adults of 70 to 80 yrs	0.33 to 0.35 mm.

Elastic tissue appears in the lungs in the fifth or sixth fetal month. It develops very slowly until birth, but it increases with great rapidity in the first month of post-natal life.

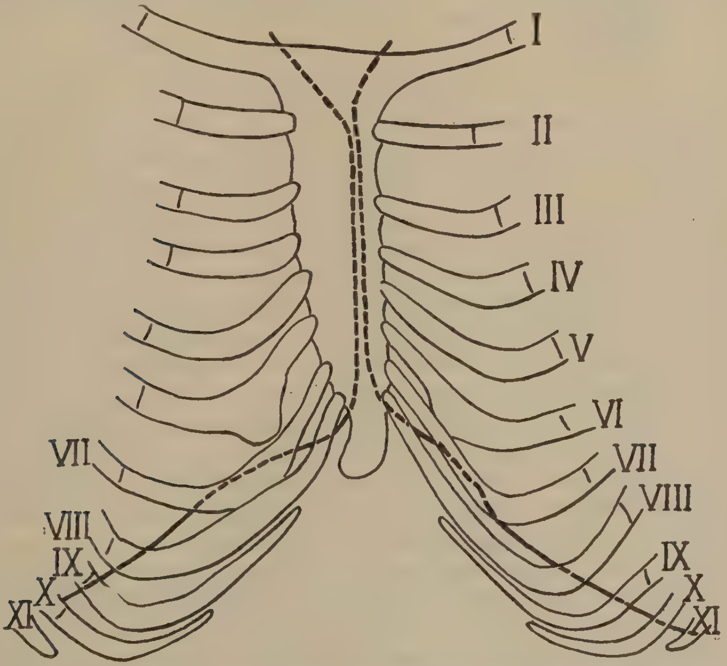

Fig. 142.—Outline of the skeleton of the anterior thoracic wall of a newborn child showing the common lines of pleural reflection in infancy. The numbers of the ribs are indicated in Roman numerals. (Based upon the figures and descriptions of Tanja.[162])

THE PLEURA (Figs. 122, 123, 142)

The only extensive series of observations upon the topography of the pleural sacs in infancy is that of Tanja[162] and the following statement is summarized from his descriptions. The medial margins of the pleural sacs generally meet behind the sternum, extending almost the entire length of that bone a little to the left of the median line. The left line of pleural reflection turns away from the sternum at the level of the sixth rib, the sixth interspace, or the seventh rib; the right one a little lower at the level of the seventh rib or along the upper part of the xiphoid process. In over one-half the cases the inferior pleural margins pass across the costal cartilages of the ribs from the seventh downward. The inferior pleural margin commonly joins the medial posterior one at the level of the twelfth thoracic vertebra. As in the adult, the posterior lateral margins of the pleural sacs extend upward to the level of the last cervical vertebra. The skeletal relations of the apices of the sacs are much the same as those of the adult. Certain variants from this general scheme are common. The anterior medial margin of the left pleural sac may not extend inward to the sternum, and sometimes the two sacs do not meet anteriorly. The posterior inferior angle of the sacs may lie as low as the first lumbar vertebra or as high as the eleventh thoracic vertebra. Figure 142 is a diagram showing the usual lines of the pleural reflections on the anterior chest wall in infancy.

THE UROPOIETIC ORGANS

THE KIDNEYS (Figs. 122, 123, 129, 132, 143, 144, 145, 147, 156)

The absolute weight of both kidneys in the newborn is between 20 and 25 gm. This weight is doubled in six months, quadrupled in the first two years, and increased about eight fold by puberty. The average weight of the kidneys in the adult is from 10 to 14 times that of the newborn. Although the absolute weight increase is great, the kidneys show a decrease in relative weight in post-natal life. At the time of birth and for nearly five years thereafter they form 0.65 to 0.75 per cent. of the entire body weight. After five years the relative kidney weight decreases slowly until after puberty when the adult relation of about 0.5 per cent. is reached. Although the kidneys are rarely of equal weight at the time of birth the examination of a large series of cases shows the right to be the heavier in almost as many instances as the left. By the second year, however, the left kidney is commonly the heavier one as it is in maturity.

At birth the kidneys average 4 to 5 cm. in length, 2 to 2.5 cm. in breadth, and 1.2 to 1.5 cm. in thickness. The length and breadth of the kidneys increase about two and one-half times by maturity and the thickness about two times. The kidneys are thus somewhat thicker proportionally in the infant than in the adult.

The most striking characteristic of the infant's kidney is its marked lobulations. These are ordinarily obliterated in the fourth or fifth year although they may occasionally persist in the adult. In certain mammals, such as the sheep and the bear, they are found throughout life. The number of lobules is extremely variable, being anywhere between 5 and 25. There is no relation between the number of lobules and the number of renal papillæ.

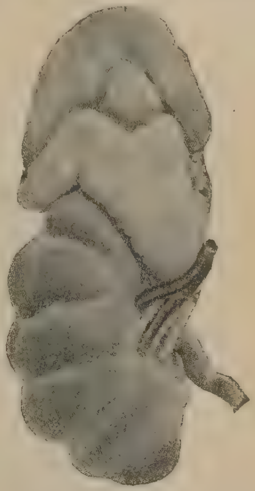

FIG. 143.—Anterior view of the left kidney and suprarenal of a newborn child 52 cm. long. Natural size.

Both the skeletal and the visceral relations of the kidneys in the young infant are quite different from those of later life. The differences in the skeletal relations are due mainly to the large size of the kidneys and the shortness of the lumbar portion of the posterior abdominal wall. The relation of the lower poles of the kidneys to the iliac crests has been studied by Alglave,[164] who found that in a series of 32 children under six months of age the lower poles of the kidneys were below the iliac crests in one-half of the cases, on the crests in a little over one-quarter, and above the crests in the remainder. In the second year the lower poles were on the crests in one-third and above the crests in two-thirds of the cases. The lower poles of the kidneys were above the crests in all children over two years of age. The upper poles at birth, according to the observations of Baduel,[165] lie at the eleventh intercostal space or the margins of the ribs bounding it and during childhood at the level of the twelfth rib. Banchi[166] examining 100 newborn children, found that the upper poles of the kidneys commonly lie at the twelfth thoracic vertebra, or the disc immediately above and below it, and the lower pole at the fourth or fifth lumbar vertebra. In the newborn and the young infant the left kidney lies higher than the right in about two-thirds of all cases. Although the kidneys are much more movable in the child than in the adult their change in position is probably a passive one dependent upon the rapid growth of the neighboring skeletal parts and their associated muscular structures.

In the infant the anterior surface of the right kidney is in contact with the cecum, the ascending colon, the right suprarenal, and the liver. Relatively the suprarenal has a much larger contact area than in later life while the hepatic area is relatively smaller. The right margin of the descending segment of the duodenum generally comes in contact with the hilus of the right kidney. The left kidney is in contact anteriorly with the left suprarenal, the descending, and, sometimes, the transverse colon. At birth and for a very short space of time thereafter the left kidney is not commonly in relation with the spleen. Occasionally the tail of the pancreas may touch the kidney just below the inferior margin of the suprarenal.

As is well known, the tubules of the kidney are formed in a series of from 14 to 18 generations. The glomeruli of these several generations are arranged, in the young kidney, in roughly concentric layers of which the inmost is the oldest in origin and the peripheral the most recent. The exact time of formation of the last or peripheral generation of tubules is a matter of considerable controversy. The date has been variously placed from the ninth or tenth fetal month to the end of the first post-natal month. Although there may be considerable individual variation in this particular, one is inclined to suspect that congenital lues may be responsible for the delayed date of cessation of tubule formation which some authors have observed in their material. The kidneys have acquired approximately one-tenth of their final weight at the time when new tubule formation ceases; it follows, then, that fully 90 per cent. of the growth of the renal parenchyma is in the form of tubule hypertrophy. Our knowledge of the nature of the post-natal changes in the renal tubules rests mainly on the micrometric studies of Eckardt[169] and of Külz.[175] These observations show that the central or older glomeruli are very much larger than the peripheral ones at the time of birth. The central glomeruli grow steadily in size until after puberty by which time they

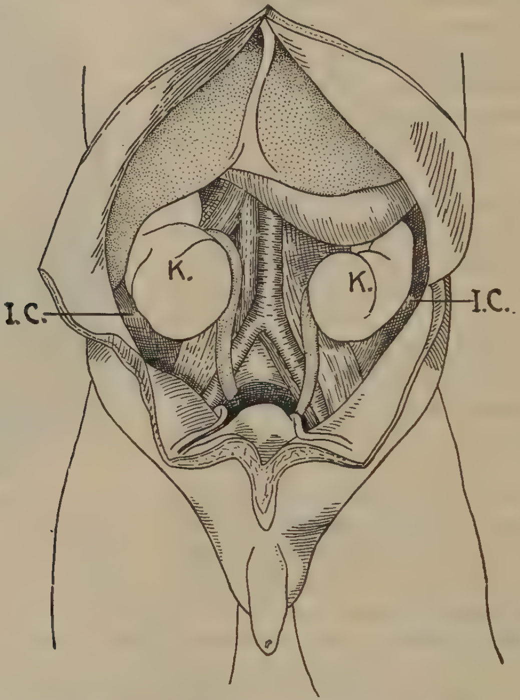

FIG. 144.—A dissection of the posterior abdominal wall of a male child one month old showing the position of the kidneys. I.C., iliac crest; K., kidney. (After Alglave.[164])

have doubled in diameter. The peripheral glomeruli grow at a more rapid rate than do the central ones; but do not equal them in size until after puberty. The ascending and descending limbs increase but little in diameter between birth and maturity. The most active segments are the convoluted tubules. These increase in diameter very rapidly during the first three or four years of life. Thereafter their diameter increases very little, but they enter a period of longitudinal growth which lasts until after puberty. The growth of the collecting tubules is apparently slight.

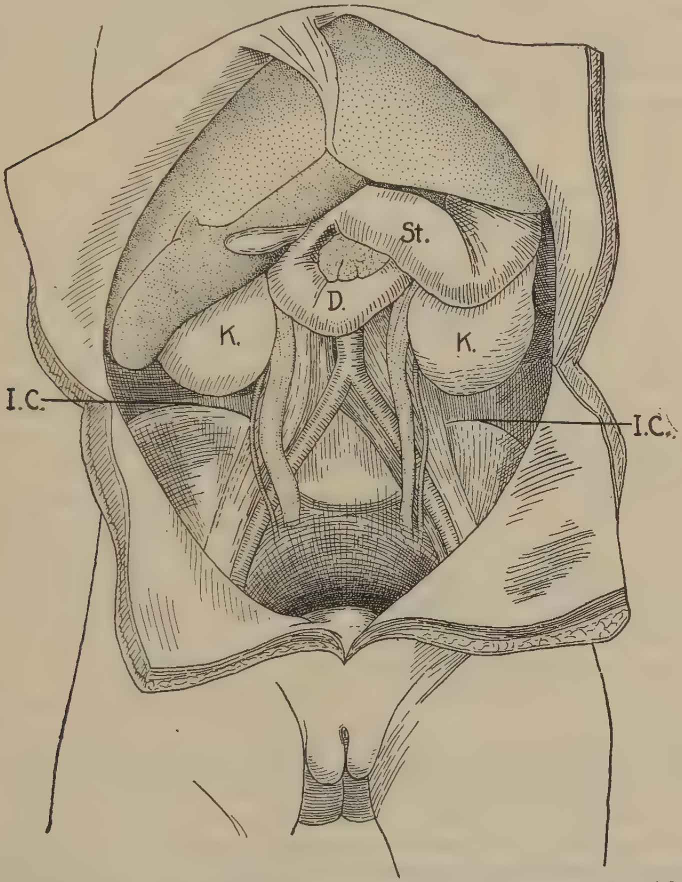

FIG. 145.—A dissection of the posterior wall of the abdomen of a girl two and one-half years old showing the position of the kidneys. D., duodenum enclosing the head of the pancreas; I.C., iliac crest; K., kidney; St., stomach. (After Alglave.[164])

No volumetric studies have been made of the cortex and medulla in childhood. In the newborn the cortex is one-fifth or one-fourth the thickness of the medulla and in the adult from one-half to two-thirds. Apparently most of the increase in thickness of the cortex takes place in the first eight years of life. Lineal measurements of the cortex and medulla are very inaccurate and the proportions just citied are only approximate ones.

THE URETERS (Figs. 144, 145, 147, 148)

The ureters are from 6.5 to 7.0 cm. in length in the newborn, being a little less than one-fourth as long as in the adult. The left ureter is generally a little longer than the right throughout life. The ureters practically double in length during the first two years together with the growth of the lumbar region; thereafter their growth is much slower. The diameter of the ureter in the infant is always relatively and sometimes absolutely larger than in the adult. The sinuses of the ureter are well marked and the lumbar one, in particular, is very prominent (Fig. 147).

THE BLADDER (Figs. 121, 132, 146, 147, 151, 153)

In the newborn and young suckling the contrated bladder is a fusiform organ broader below and tapering very gradually above, becoming continuous with the obliterated urachus at its apex. It is in contact with the anterior body wall over a triangular area of which the base is formed by a horizontal line drawn a little below the upper margin of the symphysis pubis, and the sides by the hypogastric arteries. The apex of the contracted bladder in the newborn lies at a point mid-way between the pubes and the umbilicus. The long axis of the bladder in the infant is often nearly vertical and falls directly in line with that of the prostatic urethra, or at most forms a wide angle with it. The thickest part of the contracted bladder in the newborn lies at about the level of juncture of its lower and middle thirds. From this plane all the surfaces of the organ slope downward and inward toward the urethral orifice. Thus the lower part of the viscus has the form of a funnel, flattened slightly anteroposteriorly, and there is no true fundus such as is seen in the adult bladder. According to the measurements of Uteau,[178] the trigone of the contracted bladder in both sexes in the first year of life forms an equilateral triangle the sides of which are approximately 1 cm. in length. These dimensions are about two-fifths those of the adult.

The moderately distended bladder of the infant is egg-shaped with its larger end directed forward and upward. According to the measurements of Birmingham,[167] the organ when in this condition lies approximately half in the abdominal and half in the pelvic cavity. The fully distended bladder in children is almost completely an abdominal organ and may extend upward to the level of the umbilicus. Fig. 146.

The descent of the bladder after birth has been carefully studied by Disse.[168] He recognizes four stages in this process: First, a period of rapid descent extending from birth to the beginning of the fourth year; second, a period from three to nine years in which the descent is slow but continuous; third, a stage extending from nine years to puberty in which the bladder remains stationary; and fourth, a period from puberty to the end of the second decade in which the organ completes its descent.

As the bladder descends into the pelvis, the opening of the urethra is shifted farther and farther away posteriorly from the symphysis pubis. At the same time the apex of the bladder descends rapidly along the anterior abdominal wall and comes to lie, in the completely contracted bladder, at a level but little above that of the urethra. In this way the axis of the bladder is changed from the vertical to the horizontal plane of the body. This change in axis is generally completed by the end of the third or fourth year. The form of the fully expanded bladder is approximately the same in the newborn and adult.

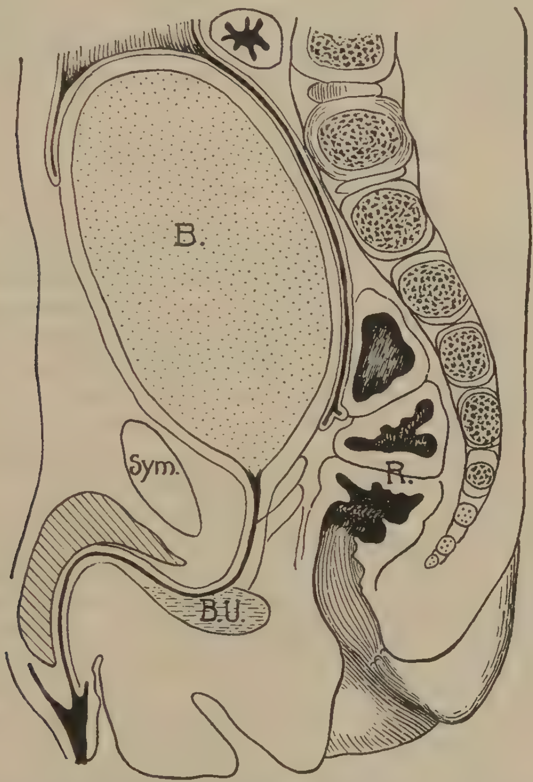

FIG. 146.—A median sagittal section of the pelvis of a male infant 9 months old with the bladder distended. B., bladder; B.U., bulbus urethræ; R., rectum; Sym., symphysis pubis. (After Symington.[14])

The capacity of the bladder at birth and in later life is extremely variable, and the available figures regarding it are probably not very valuable. Birmingham[167] injected the bladder of a newborn male in situ with a gelatin solution at a pressure of 6 to 8 cm. of water, and found the bladder contents to be 27.8 c.c. Kalaschnikoff (quoted by Gundobin[7]) found the average capacity of the bladder of the newborn, when removed from the body, to be 50 c.c. The latter author found the capacity to be more than doubled in three months and nearly quadrupled by the end of the first year.

The urachus of the infant does not differ greatly, except in length, from that of the adult. Its lumen is normally obliterated in the fourth or fifth month of fetal life, and although portions of the canal may remain in the form of cysts or diverticula of the bladder these are probably no more numerous in the newborn or child than in the adult.

THE MALE GENITAL ORGANS

The Testes (Figs. 147, 149)

The two testes with their epididymides weigh about 2 gm. at the time of birth. This weight is doubled in the first two years of life. Thereafter the weight increase is very slow, the average weight in the thirteenth or fourteenth year being about 4 gm. Between this time and the sixteenth year, *i.e.*, with the establishment of puberty, the weight of the testes and epididymides increases fivefold to 20 gm. The testes continue to increase, although in varying degrees, at least to the twenty-fifth year when they weigh 40 to 50 gm. According to Vvedenski's[193] observations, the right testis is the heavier in early infancy while in later life the left is the heavier one.

The relative weight of the testes is almost the same in the newborn and the adult. The testis in the newborn is, on the average, 10 mm. long and 5 mm. in breadth and thickness. It increases four times in length and somewhat more than four times in breadth and thickness between birth and maturity. The long axis of the testis is practically vertical in the infant, whereas it is directed forward and outward as well as upward in the adult.

Sections of the testes of the newborn show small convoluted or contorted tubules separated by a large amount of delicate connective tissue. The tubules are 60 to 80 micra in diameter and are generally solid. They are made up of small undifferentiated sustentacular cells and larger and less numerous germ cells (spermatogonia). Interstitial cells of Leydig are found in the connective tissue septa either singly or gathered in small groups. During childhood the contorted tubules slowly increase in diameter and acquire central lumina. The spermatogonia increase in number and size, and the sustentacular cells tend to gather in a definite layer at the periphery of the tubules. The connective tissue does not increase at a rate equal to that of the tubules and therefore forms less and less of the mass of the testis. With puberty the seminiferous tubules enlarge rapidly, the sustentacular cells take on their characteristic adult form, and the germ cells begin the process of maturation. The cytologic changes in the germ cells at puberty have not been studied in detail in man. The interstitial cells of Leydig are said to increase in number from birth to puberty.

DESCENSUS TESTICULORUM AND THE TUNICA VAGINALIS (Figs. 147, 150)

The testes are intra-abdominal in position during the greater part of fetal life and only reach their permanent scrotal position in the eighth month. In fetuses of the latter part of the second month they are a pair of narrow elongated bodies extending from the upper lumbar region to or into the upper sacral region. The upper part of the genital mass undergoes degeneration while the lower portion remains to form the definitive testis. In the third fetal month the testes are found in the iliac fossæ. This change in position is brought about not by the active migration of the structures, but mainly by the atrophy of their cranial parts. At this time the testis possesses a mesorchium of complex and multiple origin. The caudal part of this fold extends from the lower pole of the testis to the point on the anterior abdominal wall where the inguinal canal will be formed. In the core of this fold as well as along the line of its attachment to the abdominal wall there is developed a band of fibro-muscular tissue which is known as the gubernaculum testis. This band secures its attachment in the region of the future scrotum before the definite muscular layers of the abdominal wall are differentiated. When these layers are formed they grow around this band.

The testes lie at the site of the future abdominal ring from the fourth until the seventh month of fetal life. In the meantime the abdominal wall in this region becomes greatly thickened and by a series of complex changes the caudal end of the peritoneal cavity on either side is reduced to a small diverticulum, the beginning of the processus vaginalis. The lower pole of the testis often lies just within the upper part of this sac which has, in fact, grown up around it. The processus vaginalis eventually passes through the anterior abdominal wall and, extending over the pubis, invades the scrotum which is solid at this time. In doing so the tunica passes into an interval which is already formed in the abdominal musculature. The gubernaculum testis and the tunica vaginalis both pass down into the scrotum carrying the several layers of abdominal musculature and fascia before them. The latter become the fascial investments of the testis. During the seventh month the testes, which are already partially enclosed by the upper end of the tunica vaginalis, pass down through the inguinal canal, and by the middle of the eighth month are generally attached to the fundus of the scrotum. The left testis generally descends a little in advance of the right. The chronology of the process of descent is generally quite regular and the records of a large series of cases show the testes to be in their final position in over 90 per cent. of newborn children.

Much has been written on the cause of the descent of the testes but the subject is still far from clear. As has been pointed out in the

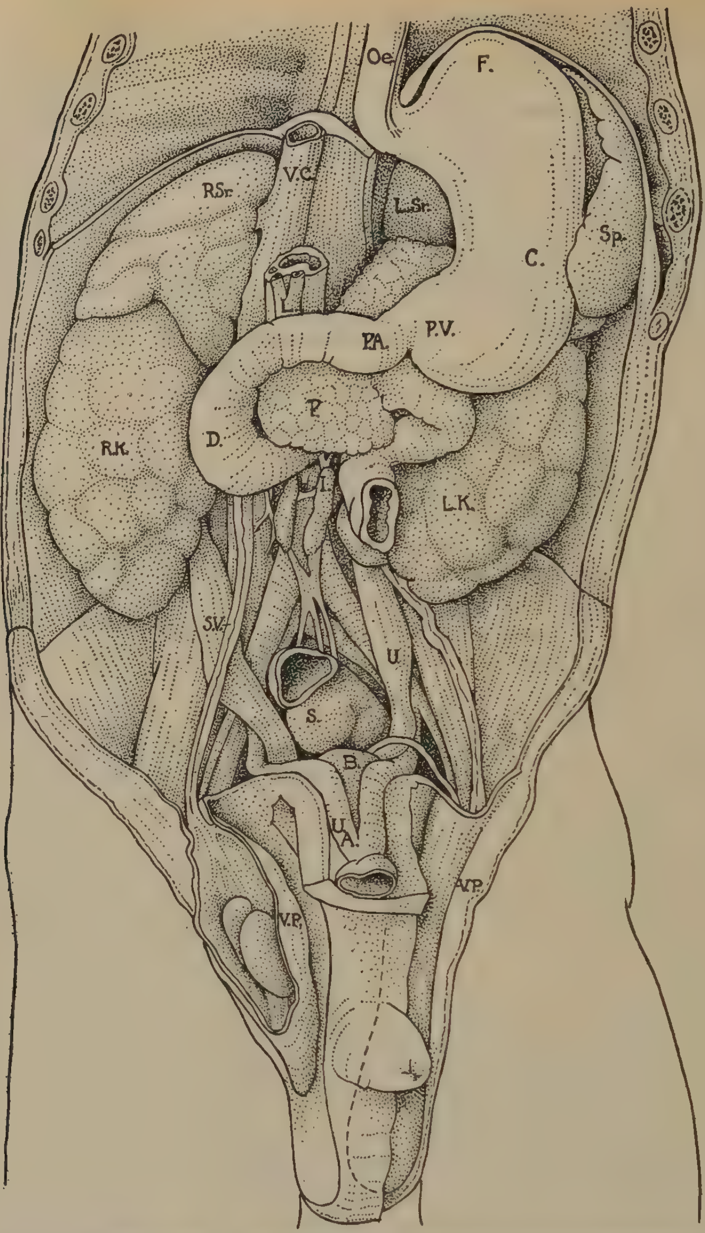

FIG. 147.—Dissection of the posterior wall of a still-born, premature infant. The liver and the greater part of the intestine have been removed. The right processus vaginalis has been opened exposing the testis, epididymis and gubernaculum. B., bladder; C., corpus of stomach; D., duodenum; F., fundus of stomach; I., aortic bodies (organs of Zuckerkandl); L., hepatoduodenal ligament, common bile duct and portal vein; L.K., left kidney; L.Sr., left suprarenal; Oe., esophagus; P., pancreas; P.A., pyloric antrum; P.V., pyloric vestibule; R.K., right kidney; R.Sr., right suprarenal; S., sigmoid colon; Sp., spleen; S.V., spermatic vessels; U., ureter; U.A., umbilical arteries; V.C., vena cava inferior; V.P., vaginal process. Natural size.

preceding paragraphs, the shifting in position of the testes within the abdominal cavity is due not to an actual descent of the organs, but at first to the degeneration of their cranial parts, and later to the conversion of a portion of the cranial part of the abdominal cavity into the tunica vaginalis. The part played by the testes themselves is entirely passive. The movement of the testes through the inguinal canal is, however, an actual descent. Among the factors suggested as causing this descent are the pressure of the rapidly growing abdominal viscera, the shortening of the gubernaculum (first through actual contraction of its muscle fibers and later by its shrinkage during atrophy), the vertical position of the inguinal canal in the fetus, and finally the "inequality of growth in the tissues."

The processus vaginalis communicates with the general peritoneal cavity above in nearly two-thirds of all children under two weeks of age, according to the extensive series of observations of Engle[182] and of Sachs.[190] After this time, however, the obliteration of the communicating canal is very rapid, more than 80 per cent. of the cases between 10 and 20 days showing partial or complete obliteration. The table of Sachs is given in summary below.

The left communication is generally obliterated some time before the right one and when both are present the left opening is almost always the smaller. This finding is in accord with the greater frequency of right inguinal hernia and with advanced descent of the left testis. Lockwood[186] described the obliterative process as taking place at two points, one near the upper and one near the lower end of the inguinal canal. This is not confirmed by the observations of Sachs who found the process beginning in the middle third of the portio funicularis, and extending upward and downward from this point.

TABLE 21.—THE POST-NATAL OBLITERATION OF THE PROCESSUS VAGINALIS (AFTER SACHS[190])

Age	Number of cases	Condition of processus vaginalis in percentages			
		Obliterated	Open above	Entirely open	Total of cases of incomplete or total lack of obliteration
0 to 10 days.....	27	20	19	61	80
10 to 20 days....	40	50	32	18	50
20 to 30 days....	15	47	23	30	53
30 to 60 days....	25	36	34	30	64
60 to 90 days....	22	36	39	25	64
90 to 120 days...	13	65	16	19	35
120 to 335 days..	13	69	27	4	31

THE PROSTATE (Figs. 146, 148)

In its growth, the prostate follows closely the history of the structures of the male genital tract. Arising in the latter part of the third fetal month, the gland grows slowly for a period; but one or two months before birth it begins to increase at a rapid rate and between this time and birth its weight is doubled. From birth until a short time before puberty, the prostate grows very slowly and the gland hardly doubles its weight in the first decade of post-natal life. From puberty or shortly before puberty until the middle of the third decade, the prostate again grows rapidly, particularly before the twentieth year.

The dimensional changes of the prostate are similar to those of weight; during childhood they are augmented very slowly but during and after puberty very rapidly. Although subject to great individual variation it may be said that the length, breadth, and thickness are usually tripled between birth and maturity. The chestnut form so often assigned to the adult prostate is less noticeable in childhood; at this time the organ is more conical in shape and the lateral borders, which are prominent in the adult gland are rounded and merge into the surfaces.

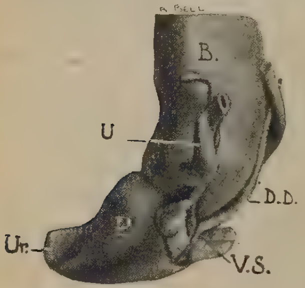

FIG. 148.—Base of the bladder and the prostate gland of a full-term newborn child. B., bladder; D.D., ductus deferens; P., prostate; U., ureter; Ur., urethra; V.S., seminal vesicles.

The prostatic urethra is approximately 1 cm. in length in the newborn; it is two and one-half times longer in the adult. Apparently most of the length increase takes place after puberty.

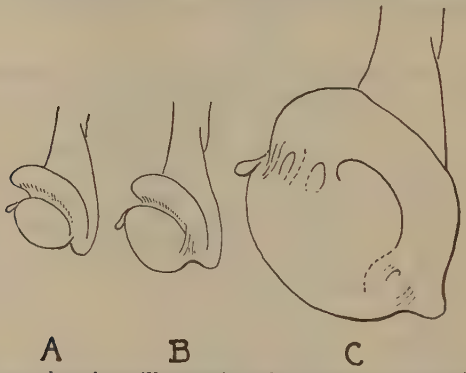

FIG. 149.—Three drawings illustrating the growth of the testis and epididymis and the postnatal changes in the digital fossa. A., newborn. B., child of two years. C., adult. All enlarged one and one-half times. (After Poirier, Rev. de Chir., X.)

The finer structure of the prostate in childhood has been recently investigated by Lowsley[187, 188] and Hada,[185] and the following outline is based mainly on the accounts of these authors. The total adult number of prostatic tubules is already present at the time of birth and the post-natal increase in glandular tissue is brought about by the enlargement of these elements. In the newborn the tubules have the form of elongated and irregular sacs which often end in dilations and which may have lateral outpouchings. The terminal portions of the glands may be solid at birth, but they acquire lumina in early infancy. The tubules grow very slowly during childhood but at puberty they increase greatly in caliber and give off many lateral branches, particularly from their distal portions. Lowsley estimates that the glandular tissue forms one-third of the prostate in fetuses and newborn children, and one-fourth of the prostate after puberty. As in later life, the epithelium lining the tubules is extremely variable in height. Lowsley has also investigated the post-natal history of the small groups of glands which are associated with but are not, properly speaking, part of the prostate (the subcervical glands of Albarran, the subtrigonal glands and the apical glands). He finds that, unlike the true prostatic glands, they increase in number from birth to puberty.

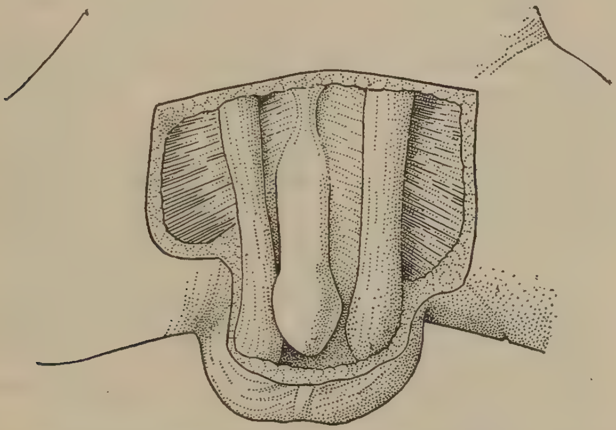

FIG. 150.—Superficial dissection of the external genitalia of a newborn male child. Natural size. (After Credé-Hoerder.[181])

The muscular tissue of the prostate is weakly developed in children, but increases rapidly along with the rest of the gland at puberty. Elastic tissue is confined mainly to the center of the gland until puberty when it also is greatly increased.

Schlachta[191] has described a natal secretion of the prostate which is present in the late fetus and which disappears shortly after birth. True prostatic concretions are not found in the prostates of children although masses of a colloid eosinophile substance sometimes occur in the lumina of the prostatic tubules.

THE URETHRA AND PENIS (Fig. 150)

The male urethra is 5 or 6 cm. long in the newborn. The details of its later growth are shown in Table 22 which is a summary of the measurements made by Zwineff (quoted by Gundobin[7]). As will be seen from this table, the urethra practically triples its length between birth and maturity and the rate of increase is a fairly regular one except for a slight acceleration at puberty. Most of the growth takes place in the cavernous urethra.

The structure of the urethra and penis is quite similar in the infant and adult. Urethral glands and lacunæ are already present at the time of birth although they increase both in size and number during childhood. The erectile tissue of the infant differs from that of the adult in the weaker development of the smooth muscle bundles and scarcity of elastic fibers.

During the greater part of fetal life the epithelium covering the glans penis and that lining the inner surface of the prepuce are fused together in a single plate. The separation of the prepuce from the glans begins as early as the fifth month of fetal life but is almost always incomplete at birth and may remain so for some time thereafter.

TABLE 22.—THE LENGTH OF THE MALE URETHRA IN CHILDHOOD (Based upon the Data of Zwineff and Waldeyer)

Age	Number of cases	Length of urethra (centimeters)			
		Total	Pars cavernosa	Pars membran.	Pars prostat.
Newborn	..	5.6			
1 month	4	6.2	4.6	0.8	0.8
1 year	2	6.7	5.25	0.65	0.8
2 years	4	7.6	5.3	1.0	1.3
3 years	6	8.1	6.2	0.9	1.0
5 to 6 years	6	9.4	7.4	0.9	1.1
8 to 10 years	8	10.4	8.2	1.0	1.2
11 to 12 years	4	11.1	8.9	1.0	1.2
13 to 14 years	4	11.9	9.2	1.1	1.6
15 to 16 years	4	15.7	12.2	1.5	2.0
Adult	..	18–20			

THE SCROTUM AND SPERMATIC CORD (Figs. 106, 150)

The scrotum of the infant is relatively short and broad and the distinction between the fundus and neck of the sac is not noticeable until a year or more after birth. Both the peripheral walls and the septum are relatively much thicker in the infant than in the adult.

The spermatic cord is also relatively thicker in the infant than in later life. Its circumference in the suckling is almost as great as that at puberty, and more than half that of the average adult. In the newborn and suckling the cord passes almost vertically from the base of the scrotum through the inguinal canal. The cremaster muscle is highly developed in the infant.

THE FEMALE GENITAL ORGANS

THE OVARIES (Figs. 151, 152, 153, 155)

During the latter part of fetal life the ovaries grow very rapidly. Their average weight in the newborn is about 0.3 gm. The rapid growth of the ovaries is continued in early post-natal life, and the structures double their weight in the first six months. The birth weight of the ovaries is tripled by the end of the third year, and increased seven- or eight-fold by the end of the tenth. Such statistics as we have, indicate that the weight of the ovaries is nearly doubled

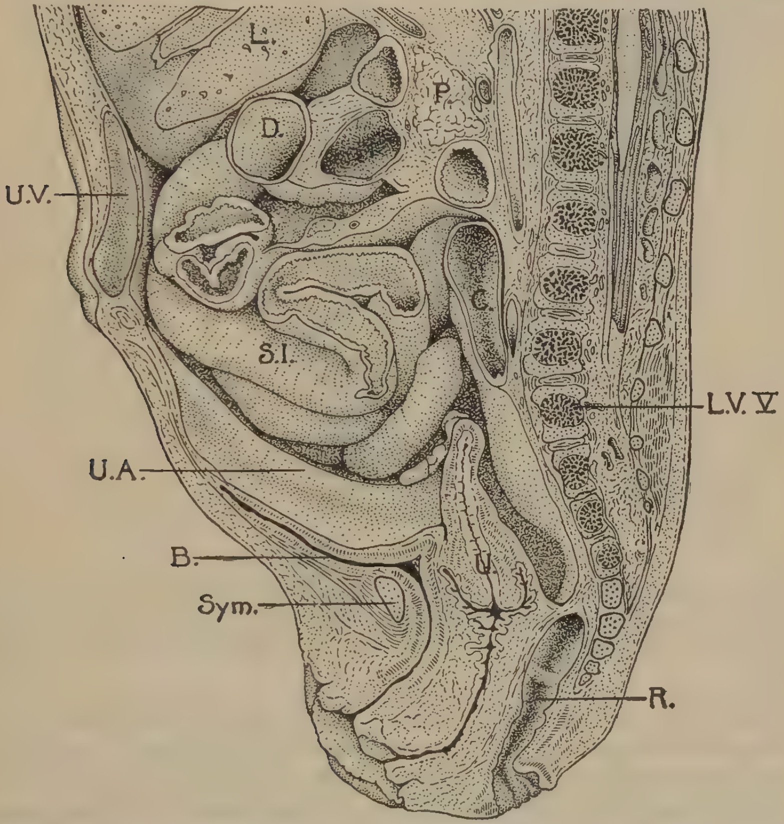

FIG. 151.—Median sagittal section of the pelvis of a full-term, newborn female child; B., bladder; C., colon; D., duodenum; L., liver; L.V.V., fifth lumbar vertebra; P., pancreas; R., rectum; S.I., small intestine; U., uterus; U.A., umbilical artery; U.V., umbilical vein. Natural size.

between 12 and 15 years, and the total weight increase from birth to maturity is about sixteen fold. The ovaries show great individual variation in weight throughout childhood because of the fluctuation in the development of the vesicular or Graafian follicles during this period. The variation in the relative weight of the ovaries during childhood is so great that no general statements can be safely made regarding it.

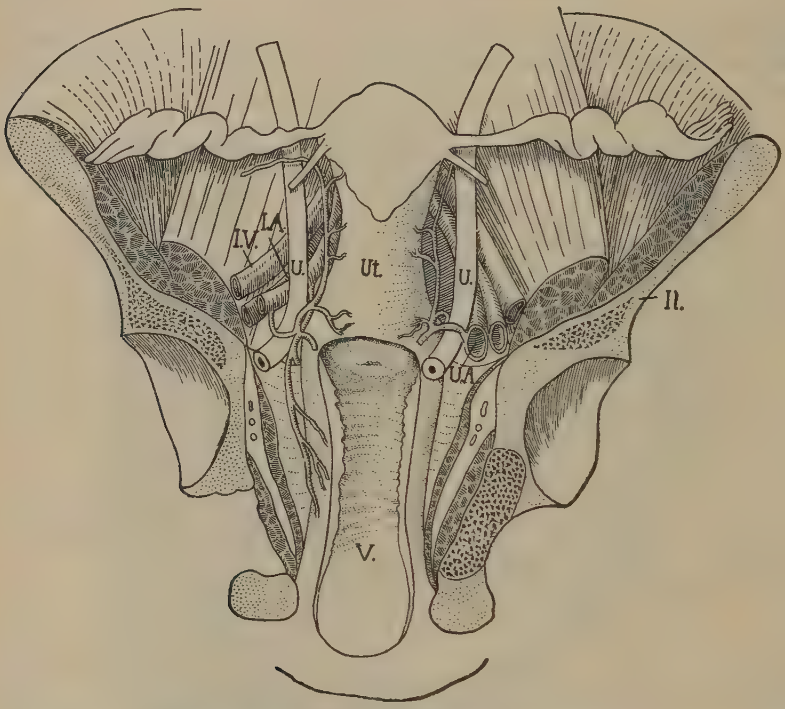

Fig. 152.—Semidiagrammatic frontal section of the pelvis of a newborn female child. I.A., external iliac artery; Il., ilium; I.V., external iliac vein; U., ureter; U.A., umbilical artery; Ut., uterus; V., vagina. (After Fredet, Thèse, Paris, 1899.)

The form of the ovaries is quite variable in early childhood. At birth they are from 15 to 30 mm. in length and 4 to 8 mm. in breadth. They are generally triangular in cross section in their central portions, but are rounded at their extremities. With the great development of vesicular follicles in the first two or three years of life the ovarian surfaces become rounded and the furrows which often indent them at birth disappear.

The ovaries, like the testes, change from an abdominal to a pelvic position during fetal life. According to the observations of Wendler,[220] they lie in the middle of the lumbar region at the beginning of the third fetal month, at the upper margin of the iliac crests at the beginning of the fourth month, and well in the iliac fossæ by the middle of the fifth month. In the newborn they are generally found at the lower margin of the iliac fossæ. Their passage over the iliopectinal line into the fossa ovarica immediately below it generally takes place in early childhood; but it may be accomplished before birth, or be delayed until puberty, or sometimes may not occur at all. The long axis of the ovary is in the sagittal plane of the body in the young fetus, but as the descent takes place the upper pole is rotated outward and the axis comes to lie in the transverse plane. As the ovary reaches its permanent position in the fossa ovarica above the larger pelvic vessels and posterior to the broad ligament, the lateral or superior pole is shifted backward and the long axis of the organ again falls in the sagittal plane of the body.

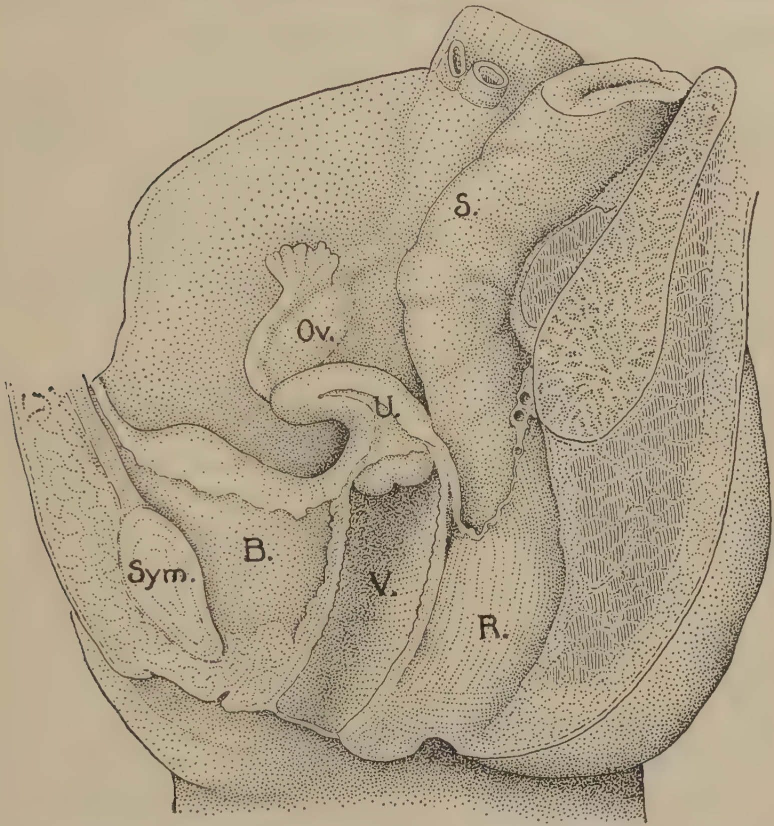

Fig. 153.—Dissection of the pelvis of a girl ten years old. B., bladder; Ov., ovary; R., rectum; S., sigmoid colon; Sym., symphysis pubis; U., uterus; V., vagina. (After Boullard.[199])

Associated with the descent of the ovaries is the canal or diverticulum of Nuck which is the homolog of the processus vaginalis of the male. This diverticulum is open in about 20 per cent. of female children under one year of age. The right diverticulum is open more often than the left, as is the case with the processus vaginalis in the male.

The cortex of the ovary of the newborn is sharply marked off from the medulla and forms relatively a much larger part of the organ than in later life. It is composed mainly of primordial follicles which are separated by a very small amount of delicate connective tissue. Generally 20 to 25 rows of follicles can be counted between the inner and outer margins of the cortex. The number of follicles at birth has been estimated as high as 400,000 or even 800,000, but these figures are undoubtedly far too large and more modern calculations have put the number at from 40,000 to 80,000. During childhood and adolescence there is a great reduction in the number of ova but the time of this decrease apparently varies greatly in different individulas. Hansemann,[205] estimated the number of ova in a series of children's ovaries as follows: Six and one-half months, 30,000; two years, 48,000; eight years, 26,000; ten years, 21,000; and fourteen years 16,000. The number of ova in the eighteenth year has been calculated at 5,000 to 7,000. Thus there is a decrease of approximately 90 per cent. in the number of ova between birth and full sexual maturity.

Graafian, or vesicular, follicles are found in the ovary as early as the seventh month of fetal life and are often present in the ovaries of newborn children. During the first and second years they are formed in large numbers from the primary follicles, and by the end of this period they occupy the greater part of the ovarian cortex. The fate of the Graafian follicles formed in childhood has been the subject of a number of investigations. Undoubtedly the great majority undergo atresia before reaching complete development. However, corpora lutea have been observed, although rarely, in the ovaries of newborn and older children and the possibility of occasional ovulations is not excluded. Probably all the egg cells of the newborn child are oocytes of the first order and if this is the case there can be no production of new ova after birth. The presence of two or more ova in a single primordial or Graafian follicle is not unusual in children. Interstitial cells which lie imbedded in the stroma of the ovary and are not associated with the ovarian follicles are numerous in the fetus and apparently reach their highest development at or before birth. Interstitial cells derived from the theka cells of atretic ovarian follicles appear shortly after birth and increase in number until puberty (Fraenkel[204]).

Space will not permit a discussion of the vascular changes in the ovary during childhood. This subject is described in detail in an excellent paper by Clark.[201]

THE UTERUS (Figs. 151, 152, 153, 154)

The uterus at the time of birth varies in length from 25 to 50 mm., the average of a series of 120 cases being 35 mm. Its weight is between 3 and 4 gm. The cervix forms two-thirds or more of the length of the uterus in the newborn, and its walls are much thicker than those of the corpus. There is no definite isthmus present at birth.

During the first few weeks of post-natal life the uterus undergoes a marked involution, in which its length decreases about one-third and its weight over one-half. This involution is due mainly to an atrophy of the uterine muscle. Although the organ shows some growth at about five or six years, its natal dimensions are rarely regained before 11 years. Usually in the twelfth year, however, a period of very rapid growth sets in and by 16 or 15 years the organ has usually attained nearly its adult weight and dimensions. Until this period of rapid growth the infantile relations of the corpus and cervix remain practically unchanged, but during this period the corpus increases rapidly in all dimensions while the cervix remains stationary. By this process of unequal growth the adult proportions are attained by the time of puberty. The isthmian segment of the uterus can hardly be distinguished during the first years of life. It is formed from the upper part of the cervix and increases but little in length after its appearance.

The uterine cavity in the child is a narrow slit-like cleft, flattened anteroposteriorly, and widest at its lateral margins. It is indented on its anterior and posterior margins by a series of folds known as the plicæ plamatæ or arbor vitæ. These generally consist, on either side, of a central longitudinal ridge from which numerous side ribs pass off upward and backward. The plicæ palmatæ usually disappear, in part at least, in the prepubertal growth period.

The thickness of the uterine mucosa in childhood varies from 0.5 to 1.5 mm. This variation shows no relation to the age of the individual. The lining epithelium consists of a single layer of cuboidal cells. The presence of cilia on the uterine epithelium in childhood has been a matter of considerable dispute but it seems that as a rule they are absent until the time of puberty. The development of the uterine glands in the child has never been thoroughly investigated, and seems to be an extremely variable process. Small mucous crypts and simple tubular glands are often seen at the time of birth opening into the bottoms of the folds which separate the plicæ palmatæ; these increase in number throughout childhood although at an extremely variable rate and without much change in form, and branched glands are rare in the uterus in childhood. The cervical glands are often represented at birth by small crypts but in the later periods of childhood they develop more slowly than the glands of the corpus. We have little knowledge of the numerous changes which must take place in the uterine glands at puberty. Baumgartner, Nelson and Dock (Am. Jour. Anat., xxvii, (1920) found a rapid growth and division of the glands at 14 years.

In the newborn child and the young infant, the uterus lies wedged in the narrow cavity of the lesser pelvis between the base of the bladder and the rectum. Consequently its position depends in a large measure on the condition of these organs. At birth the bladder contains but a small amount of fluid while the rectum is distended with meconium; as a result the uterus is pressed forward and is practically always more or less anteverted. Later in infancy, as the bladder descends into the pelvic cavity, the uterus may be both anteverted and anteflexed. With the bladder distended the uterus may be vertical or even retroflexed. The uterus is generally displaced a little to the right of the median line in the newborn, and its upper third generally lies above the plane of the superior aperture of the lesser pelvis.

THE VAGINA, EXTERNAL GENITALIA AND URETHRA (Figs. 151, 152, 153)

The vagina is from 2.5 to 3.5 cm. in length in the newborn (Ballantyne[1]). As in later life, the posterior wall is distinctly longer than the anterior one. The organ grows very slowly in childhood and rapidly in the prepubertal period, but there is apparently great individual variation in the rate of longitudinal growth. Before the menarche there is a marked increase in the number of blood vessels and the amount of elastic tissue in the vaginal walls. Post-natal involutional changes, such as occur in the uterus, have not been found in the vagina.

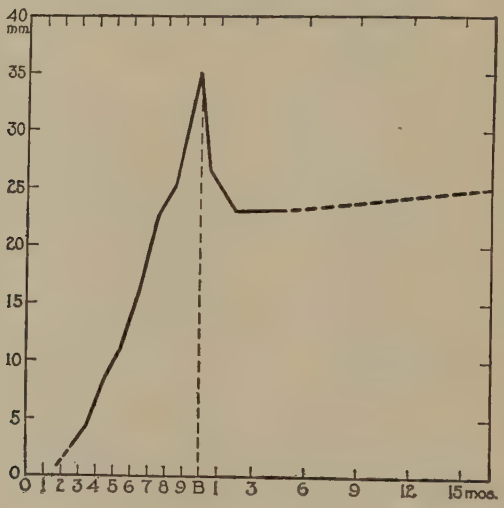

FIG. 154.—A graph illustrating the changes in the total length of the uterus in fetal and early postnatal life. B, on the base line, indicates birth. (Based upon 385 observations.)

The hymen in the infant generally appears as a thickened lip which surrounds the lower orifice of the vagina and projects somewhat into the vestibule. It is relatively thicker and more vascular than in later life and is more superficially placed. During early childhood it gradually assumes a deeper position and takes on a diaphragmatic form.

The labia majora and minor a are relatively large in infancy. The former are generally united below by a very definite posterior labial commissure. The glands of the lateral sides of the labia minor are first developed at about three years; those of the medial side at eight or nine years.

The urethra is about 1.5 cm. long in infancy and 3.5 cm. long at puberty. The diameter, as measured with the sound, is about 4 mm. in infancy and 8 to 10 mm. at puberty (Gundobin[7]). A longitudinal ridge running from the external orifice of the urethra, or the superior margin of the hymen to the base of the clitoris, is generally quite prominent in childhood.

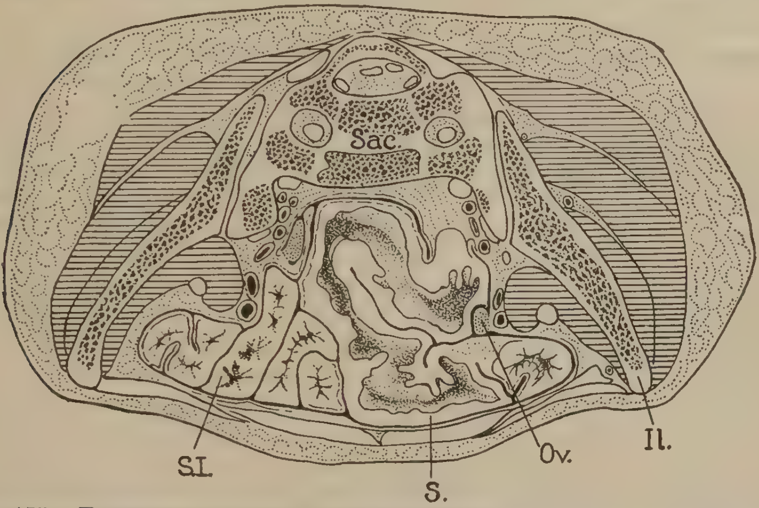

FIG. 155.—Transverse section of the pelvis of a girl 4 years old. Il., ilium; Ov., ovary; S., sigmoid colon; Sac., sacrum; S.I., small intestine. (After Dwight.[4])

THE MAMMARY GLAND

At birth and in infancy the center of the areola, which corresponds to the nipple in later years, generally lies at the level of the fourth intercostal space or the fourth rib. The average distance between the areolar centers in the first year is 9.5 cm. according to the observations of von Stark.[300] With the growth of the thorax the nipples gradually move farther apart; in the sixth year the average distance between them is about 12 cm. and at puberty about 16 cm. The lateral shifting of the nipples proceeds a little more rapidly than the increase in the transverse diameter of the thorax, so that the mammary line in maturity and later childhood is both relatively and absolutely farther from the median plane of the body than in infancy.

In the latter part of fetal life the gland is composed of 15 or 20 narrow tubules which branch several times near their termination. The terminal or secretory parts of these tubules are lined, as a rule, by a double layer of columnar cells; while the portions which represent the lactiferous ducts are lined by three or four layers of cells, although there is no sharp line of demarcation between the ducts and secretory portions of the tubules. The epithelial elements of the gland are supported by a delicate connective tissue which contains some wandering cells.

Within a few days after birth the glands begin the active production of their natal secretion or witches' milk. Witches' milk is formed in practically the same way as is the milk of adult lactation (Brouha[200]). The mammary glands become swollen and project from the general level of the thorax. The alveoli are greatly distended and the cells lining them rapidly elaborate fat-droplets which escape into the lumina of the alveoli. The connective tissue which separates the alveoli is relatively reduced and is infiltrated with lymphocytes and other wandering cells some of which pass into the lumina of the glands. As the milk is not removed from the gland the lactiferous ducts become greatly distended. The secretion of witches' milk usually ceases two or threee weeks after birth, but cellular débris and milk-corpuscles are found in the lumina of the ducts for some time thereafter. The ducts are not reduced to their natal size until six months or more after birth. According to the observations of Herz,[207] the glands are not larger in females than in males during the period of natal secretion.

The finer structure of the mammary glands during the remainder of childhood is very incompletely known, but there seems to be little change between infancy and the latter years of childhood. Before puberty the mammæ grow considerably in size, but this growth is due mainly to an increase in the amount of the interstitial connective tissue and fat. At puberty the lactiferous ducts become larger and numerous epithelial sprouts grow out from them. The elastic tissue of the gland also becomes more abundant and the vascularity increases. The male gland does not undergo these changes although there is an increase in its blood supply at puberty.

The nipple generally begins to grow above the surface of the areola in the first year of life. It is not completely formed until puberty.

THE DUCTLESS GLANDS

The Thyroid Gland (Fig. 177)

The thyroid gland generally weighs from 1.5 to 2.5 gm. in the full-term newborn. The higher averages of 4 gm. or more, which are sometimes cited in the older literature, are based in practically all instances on material collected from or near the Alpine districts of Europe where congenital hyperthyroidism is common. The weight of the thyroid at birth is about 0.06 per cent. of the body weight. The weight of the thyroid in childhood is very variable and reliable statistics on the subject are scanty. While there are a number of records of thyroid weights in children, there are comparatively few in which the material has been proven normal by histologic examination and without this proof their value is extremely doubtful. In general, the acceptable cases on record indicate that the weight of the gland increases to about 10 gm. by the tenth year, and to about 15 gm. at puberty.

The dimensions of the thyroid in childhood are as variable as the weight. Weiben found that in the first two years of life the length of each lobe was from 2 to 3 cm., the breadth from 1 to 1.5 cm., and the thickness from 0.8 to 1.2 cm. There is no particular relation between the dimensions and the age of the gland during this period. All of these dimensions are about one-half those of the mature gland. One gains the impression from dissections of the thyroid region in infants that the gland is larger in proportion to the larynx than in later life and that it covers a larger portion of the thyroid cartilage.

Our information concerning the finer structure of the thyroid gland at birth and in early infancy is still in a very confused state. Norris[243] has shown that the epithelial anlagen of the gland first breaks up into a number of plates and bands, and that follicles are formed from these structures. Follicle formation begins in the early part of the second fetal month and by the middle of the fourth month all of the original plates and bands are converted into these structures. Thereafter new follicles can be produced only by the budding or the division of older ones. Norris finds that the increase in the number of follicles up to the end of the fourth fetal month is very rapid; but that the subsequent growth of the gland, during the greater part of the remainder of fetal life at least, is due rather to the growth in the size of the follicles than to the increase in their number. Very little is known about the growth of the follicles in post-natal life. The formation of new follicles after birth by the processes of budding and division has been described by Isenschmidt[236] and Hesselberg[235] and others. Gleim,[233] who measured the follicles in a series of children from 10 days to 7 years of age, found no definite evidence of any regular increase in their size after birth.

Colloid appears in the thyroid follicles about the end of the third fetal month. It is preceded by a precolloidal material which appears granular in microscopic sections. A number of observers have described the disappearance of the colloid in the latter part of fetal life and the desquamation of the lining epithelium of the follicle into its cavity. These phenomena are not constant ones and their interpretation is not clear. Possibly they represent a pathologic process or post-mortem degeneration.

Parski[244] and Forsyth[232] claim that accessory thyroid masses are not as numerous in infants as in adults.

THE PARATHYROID GLANDS

The number of parathyroid glands is probably as variable in the child as in the adult. Forsyth,[232] who carefully examined a large series of cases, concludes that the number of parathyroids is much higher in early life than in maturity. He found an average of four parathyroids per thyroid lobe in the first year of life, 3.5 between one and five years, 1.5 in the second, and 0.7 in the third decade. Whether all the bodies which Forsyth observed in infants were true parathyroids seems, to the writer, open to question.

The dimensions of the glands are as variable as their number. In early childhood they are generally between 3.0 and 5.5 mm. long although some are microscopic in size.

At birth the glands are made up of compact masses of clear epithelial cells separated by delicate connective tissue. Faint eosinophilic granulation can be made out in some of these cells during infancy but this is subject to great variation, and well-marked eosinophilic cells are not commonly seen until about ten years Lipoid droplets appear in the epithelial cells after birth and gradually become more numerous. Colloid has been observed in the parathyroids in infancy.

Minor Epithelial Masses of the Cervical Region

Recently several investigators have noted the presence of numerous small epithelial masses, presumably of an endocrine nature, in the neighborhood of the thymus and thyroid, in infancy. These structures have been described under various titles, among others as the juxtathymic bodies, the para-parathyroid-thymic bodies, and the glandulæ insularis cervicalis. It is probable, however, that they all belong in a single category. Pepere[246] has published the most complete description of these masses. They are of small size—a few millimeters in diameter at most—and are found scattered around the thymus and the thyroid gland, and in the connective tissue of the anterior part of the neck. Their finer structure is quite like that of the adult parathyroid glands but differs considerably from that of the infantile parathyroids. They disappear about the end of the first period of infancy.

Whether these masses are, in fact, discrete organs, deserving a separate nomenclature, is, in the opinion of the writer, unsettled. It is very probable that they have been confused with the parathyroid glands in the past. This circumstance may account for the large number of parathyroids which some writers have found in infants and also for the great variation in the finer structure in the parathyroids of childhood which has been reported so often.

The Suprarenal Glands (Figs. 127, 128, 129, 132, 143, 147, 156)

The relative size of the suprarenals at birth is very great. They form approximately 0.2 per cent. of the entire body-weight in the average full-term newborn as compared with 0.01 per cent. in the average adult.

The average actual weight of the two glands at birth is about 8 gm. Although the weight of the suprarenals in the newborn may vary from 2 to 16 gm., these cases of extreme variation are not common. In a series of one hundred pairs of glands of full-term newborn children, the writer found the weight to be between 6 and 9 gm. in about one-half of the cases, between 9 and 16 gm. in about one-third, and between 2 and 6 gm. in about one-sixth. As in the adult the left gland is generally heavier than the right.

The data on the post-natal weight changes in the suprarenals are rather scanty—the three most extensive series of observations being those of Scheel,[249] Blymenau[225] and Starke and Wegrzynowski.[250] Averaging all available figures it is found that the suprarenals undergo a distinct post-natal decrease in weight, dropping from an average for both glands of about 8 gm. at birth to about 5 gm. in the first fortnight and to 4.36 gm. in the period between 14 days and three months after birth. Following this initial loss the structures increase in weight very slowly but it is probable that the initial weight is not regained until about puberty. The average weight in the third decade is about 15 gm. or a little less than twice the birth weight. There seems to be no constant sex difference in the weight of the suprarenals in childhood although the available figures indicate that in early maturity the bodies are heavier in females than in males.

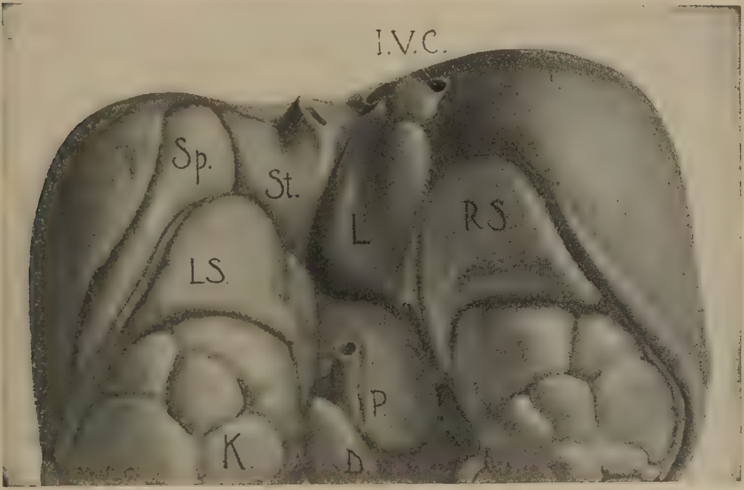

Fig. 156.—Posterior view of the suprarenals and associated viscera in a full-term newborn child. D., duodenum; I.V.C., vena cava inferior; K., left kidney; L., caudate lobe of liver; L.S., left suprarenal; P., pancreas; R.S., right suprarenal; Sp., spleen; St., stomach. Natural size.

At birth the suprarenals are generally from 2 to 2.5 cm. in length, 2.5 to 3.5 cm. in breadth and 0.8 to 1 cm. in thickness. According to the observations of Luna[241] the length and breadth remain almost unchanged in early childhood while the thickness is somewhat diminished. In the adult the length is generally from 2.5 to 3 cm., the breadth from 4 to 5 cm., and the thickness 1 cm. or a little less The furrows on the surfaces of the glands are particularly well marked at birth. At this time their margins are widely separated and rounded while in the adult they are almost in contact.

The finer structure of the suprarenal at birth is quite different from that of the adult gland. The cortex is relatively much thicker than in later life and is divided into two zones. The outer, occupying the position of the zona glomerulosa of the adult, is quite thin. It is made up of cells which have much the structure of the adult cortex cells and which are said to contain lipoid droplets. The inner layer, which occupies the position of the zona fasciculata and zona reticularis of the adult is much thicker. It is composed of larger cells arranged in columns. These cells are said to contain no lipoid. The cortex is hyperemic at birth. No pigment is found in the cortical cells in early post-natal life.

The medulla is relatively small at birth. The chromaffin cells are present but not numerous. They are arranged in anastomosing columns one cell in width. Ganglion cells are present at birth. The vascular supply is particularly rich at this time (Blymenau[225]).

The connective tissue framework of the gland is weakly developed and the elastic fibers in particular are scanty. Collections of lymphocytes along the walls of the larger vessels have been reported.

A remarkable series of changes take place in the cortex of the suprarenal during infancy. These changes were first described, I believe, by Starkel and Wegrzynowski.[250] They were reported independently by Thomas[254] a little later, and by Armour and Elliott,[224] and have been confirmed by a number of investigators since. Following the hyperemia of the cortex the large inner layer of this portion of the organ undergoes involution. The nuclei of the inner cortical cells shrink, the cells show fatty degeneration, and the columns are broken up into irregular masses. The supporting connective tissue becomes flattened into a fibrous zone around the periphery of the medulla of the gland. This involution of the inner zone of the cortex begins immediately after birth and, according to the studies of Lewis and Pappenheimer,[239] is completed by the end of the second week. The outer zone of the cortex is not affected and all of the cortex of the adult gland is formed from this portion. The regeneration of the cortex does not take place until after the first three years of life.

The topography of the suprarenals at birth is quite different from that of later life. The left suprarenal is in contact with the superior margin and the upper part of the anterior surface of the left kidney, and with the spleen, the stomach, and the body of the pancreas. In many cases the medial margin of the left suprarenal may come in contact with the liver just above the lesser curvature of the stomach. The anterior surface of the right suprarenal is in contact with the anterior surface of the right kidney, and with a large part of the inferior surface of the right lobe of the liver just lateral to the fissure for the inferior vena cava. The relations of the newborn shift rapidly to those of the adult during the first few years of life but the details of the process are not known.

Accessory Masses of Suprarenal Cortex.—Accessory masses of suprarenal cortex are very common in children. They are found both in the retroperitoneal tissue and associated with the genital organs. The retroperitoneal masses are generally found imbedded in the capsule of the suprarenal glands or lie close to these organs; but occasionally masses may be found elsewhere such as in the capsule of the kidney, the adventitia of the aorta, or the loose subperitoneal connective tissue. Their size is extremely variable; at times the suprarenals may be sprinkled with small cortical masses which are just visible to the naked eye, in other instances the bodies may be several millimeters in diameter. In male infants accessory cortical masses are commonly found in the tail of the epididymis or along the first part of the ductus deferens. These structures have been studied in detail by Wiesel.[257] He found them present in about two-thirds of all the newborn children he examined. They may occur on one or both sides of the body but are commonest on the right side only. No bodies were found in children over one year old although masses which he regarded as involuting cortical tissue were found in the epididymi of older children. Accessory masses in female infants are found in the broad ligament of the uterus for a variable period after birth (Marchand[242]).

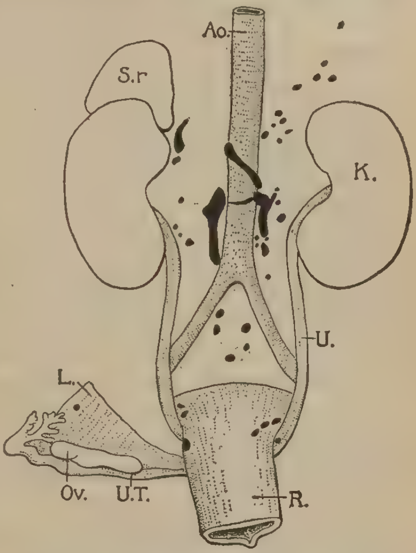

FIG. 157.—Diagram illustrating the minor chromaffin bodies of the posterior abdominal wall of a child 40 days old. Ao., aorta; K., kidney; L., broad ligament; Ov., ovary; R., rectum; S.r., right suprarenal; U., ureter; U.T., uterine tube. The chromaffin masses are indicated in solid black. (After Kohn.[237])

The structure of these masses is practically the same as that of the cortex of the suprarenal glands in the child. Lewis and Pappenheimer[239] state that involution processes take place in the accessory cortical masses as in the glands proper. In rare instances chromaffin (medullary) cells are found associated with the accessory cortical masses.

THE PARAGANGLIA (Fig. 147)

The various chromaffin bodies which are classified under this heading are well developed in early childhood. They are generally found associated with sympathetic plexuses of the larger arterial trunks, particularly those of the abdomen. The more important of these masses are listed below.

The aortic bodies, or organs of Zuckerkandl, are a pair of chromaffin masses located on either side of the abdominal aorta at the level of the origin of the inferior mesenteric artery. They are generally about 10 mm. long and 2 to 4 mm. broad. In about one-fifth of all cases the superior poles of the two masses are connected by an isthmus, but irregular forms are common. The bodies are composed of masses of chromaffin cells supported by a delicate connective tissue reticulum and surrounded by a definite fibrous capsule. They are intimately associated with the branches of the hypogastric nerve-plexus. The organs of Zuckerkandl are prominent at birth and increase somewhat in size in early childhood. In later childhood or adolescence they undergo partial degeneration and they are no longer macroscopically distinguishable in the adult, although chromaffin cells can be found in the positions which they formerly occupied.

Other minor chromaffin masses are found generally scattered in the retroperitoneal tissue of the posterior abdominal wall, associated with the female urogenital organs and the epididymis and prostate, and along the abdominal portion of the sympathetic cord.

In the thorax, chromaffin bodies occur regularly in the posterior parts of the intercostal spaces near the ganglia of the sympathetic cord. They are also found scattered along the coronary arteries, and around the base of the aorta and pulmonary artery (Busacchi[227]).

The carotid gland, which represents these bodies in the neck, has been observed in the bodies of newborn children and infants but no particular description has been given of it.

THE GLOMUS COCCYGEUM (LUSCHKA'S GLAND)

The glomus coccygeum is sometimes, probably erroneously, classified with the chromaffin bodies. Its structure in the infant has been investigated by Walker,[255] who finds that it is relatively as large at birth as in the adult and that it has in general the same form and structure as in maturity.

THE HYPOPHYSIS (Fig. 158)

The absolute weight of the hypophysis in the newborn is approximately 0.10 gm., about one-sixth the weight of the adult gland. The birth weight increases about one-half in the first year and is doubled in the third year. At seven years the body has attained about one-half its adult weight, and by the close of puberty its post-natal growth is five-sixths completed. The relative weight is much greater in childhood than in maturity. According to the statistics of Lucien,[240] it is about 0.003 per cent. at birth and in the first year, about 0.002 per cent. at puberty, and about 0.0015 per cent. in the adult. Throughout post-natal life the average relative weight is always distinctly greater in females than in males.

In infancy the hypophysis is about 10 mm. long, 7.5 mm. broad and 5 mm. thick; these dimensions are about two-thirds those of the adult body.

The anterior lobe of the infant is said to differ but little in structure from that of the adult. Both the clear, or chief, cells and the chromophile cells are present at birth, but the latter are small and few in number. The chromophile cells increase during childhood and are said by Erdheim[231] to be equal in number to the chief cells at the close of the first decennium. A distinct increase in the number of chromophile cells also occurs at puberty. The cyanophile cells appear earlier than the eosinophile. Fine fat-droplets are found in the epithelial cells at birth and increase in number throughout childhood.

The posterior lobe is richer in cellular elements and poorer in supporting fibers in infancy than in maturity. Colloid has been observed in the hypophysis both in infancy and in later childhood.

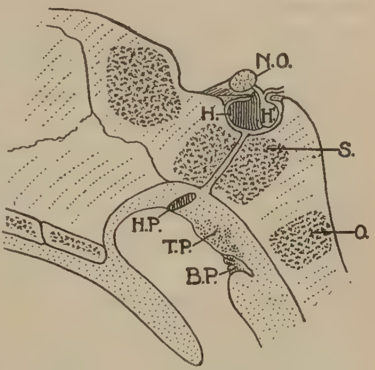

FIG. 158.—Semidiagrammatic drawing of the upper portion of the pharynx and the sphenoid bone in a newborn child illustrating the position of the pharyngeal hypophysis. B.P., bursa pharyngea; H., anterior lobe of hypophysis; H′, posterior lobe of hypophysis; H.P., pharyngeal hypophysis; N.O., optic nerve; O., ossification center of bone; S., ossification center of body of sphenoid bone; T.P., pharyngeal tonsil. The basipharyngeal canal which is shown passing through the basiphenoid bone is present in only five per cent. of children at birth. (After Testut, Traité d'Anatomie.)

ACCESSORY MASSES OF HYPOPHYSEAL TISSUE (Fig. 158)

A constant mass of hypophyseal tissue, known as the pharyngeal hypophysis, is found in the connective tissue between the epithelium covering the vault of the pharynx and the floor of the skull just anterior to the pharyngeal tonsil. It is more prominent in childhood than in later life. According to Citelli,[228] the pharyngeal hypophysis is from 2 to 5.5 mm. long in later childhood. Its finer structure is similar to that of the anterior lobe of the hypophysis proper.

In rare instances small nodules having the same structure as the anterior lobe of the hypophysis are found in the basipharyngeal canal, which sometimes pierces the body of the sphenoid bone, and also in the dura which lines the floor of the hypophyseal fossa. Figure 135 shows an example of the former anomaly.

THE PINEAL BODY (EPIPHYSIS CEREBRI)

The pineal body or gland weighs about 0.01 gm. in the newborn. This weight is increased to about 0.05 gm. at the end of the first year and to about 0.10 to 0.12 gm. at ten years. Thereafter the growth of the organ is slight, the average adult weight being about 0.13 gm. In the young child both the neuroglia and the interneuroglia (or supposedly secretory) cells can be clearly distinguished. The organ begins to undergo involution at about seven years with the formation of neuroglial placques. The process of involution is said to have reached completion at 14 years.

THE ABDOMINO-PELVIC CAVITY AND THE PERITONEUM

In the newborn the abdominal portion of the body cavity is an ovoid space which is largest superiorly. Its transverse and anteroposterior diameters are greatest at a level a little above the umbilicus. Both of these diameters are relatively greater, both in comparison to the length of the abdominal cavity and to the total body-length, than in the older child and the adult. The posterior extensions of the cavity on either side of the vertebral column are less pronounced than in later life; and the reduction in the anteroposterior diameter of the lower part of the cavity, caused by the lumbar curve, is practically absent.

The pelvic portion of the body cavity is very small both absolutely and relatively at birth. It is more elongated than in later life and its cross section more closely approaches a circle. The pelvic cavity forms a less acute angle with the abdominal cavity in infancy than later because of the absence of the lumbar and sacral curvatures.

Although newborn and infant material has often been examined in connection with studies of the peritoneal reflections comparatively little work has been done toward determining the exact differences in these structures in infancy and maturity. Such data as we have indicate that the post-natal modifications are not great. Although one often encounters the statement that the peritoneal relations in the young infant approach the embryonic type more closely than they do in the adult, the few statistics which we have do not, in general, support this view. As Reid[269] has said: "Apart from inflammation, adhesions found in the fetus and young child are scarcely if at all less extensive than those found in the adult. Practically all are developed whilst the parts are actively growing, and the most obvious causes for their formation are the pressure exerted by the relatively enormous fetal colon; the anchoring of or traction exerted by the genito-mesenteric fold of the peritoneum; and the firm resistance against pressure of the large liver. . ." All of these factors are most active some time before birth and their influence in post-natal life is probably negligible. A general description of the peritoneum is therefore unnecessary, but a few minor peculiarities seen in early life may be mentioned.

At birth the greater omentum is relatively small. Its lower margin rarely extends below the level of the umbilicus. Its structure is extremely delicate, and elastic fibers are practically absent. Fat appears in the omentum, in the immediate vicinity of the larger vessels, about the eighth fetal month but it is still scanty in the newborn and infant. The openings, or fenestra, which are sometimes found in the adult omentum are said to appear after childhood. The fusion of the omentum with the mesentery of the transverse colon begins in fetal life, but is usually incomplete at birth. The fusion of the two layers of the omentum takes place at such different periods in different individuals that no general rule can be laid down regarding it.

The general line of attachment of the mesentery of the small intestine is much the same in the infant and adult, except that it becomes more vertical with the elongation of the lumbar region in childhood. The length of the mesentery (from its attachment to the posterior abdominal wall to the intestine) is said to be relatively greater in early life than in maturity.

The peritoneal relations of the duodenum are as variable in infants as in adults but, as a rule, the attachment of the tube to the posterior abdominal wall and surrounding structures is less complete than in later life. A detailed comparison of the attachments and fossæ in this region in the newborn and the adult will be found in one of the series of papers on the peritoneum by Ancel and Cavaillon.[261]

The peritoneal relations of the ileocecal segment of the intestine in childhood are dependent to a large extent upon its position. Alglave[259] found the terminal part of the ileum and the cecum were adherent to the right kidney and the duodenum when the former structures were in the lumbar position. When in the iliac position, the cecum was found to have the 'usual' relations, with a complete covering of peritoneum and retrocolic and laterocolic ligaments, in about one-fourth of all cases. In about one-fourth of the cases it was more adherent than the 'usual' type and in about one-half less adherent. When the ileocecal segment was in the pelvic position it was always mobile. The genito-mesenteric fold (ileopelvic band), the various forms of the parietocolic fold, and more or less extensive varieties of the "bloodless folds of Treves," with their concomitant fossæ, have been observed in the late fetus and newborn by Jonnesco,[101] Reid,[268, 269] Eastman,[263, 264] and others, but our data are not sufficiently extensive to warrant a statement as to the relative frequency of these structures in early life and maturity.

The presence of an ascending mesocolon in the adult is generally regarded as the persistence of an embryonic condition but the majority of observers who have examined large series of specimens find that a mesentery in this region is less common in children than in later life. Ancel and Cavaillon,[262] in particular, found no ascending mesocolon in seventy late fetuses and newborn children which they examined, while it was present in about one-sixth of their adult cases. Furthermore, they noted that the mesocolon in the latter cases was always composed of four layers of peritoneum—indicating that it was a secondary structure derived from the posterior abdominal wall after the primary two-layered mesocolon had fused with the parietal peritoneum of this region.

The transverse mesocolon is usually of considerable length in the newborn. Its fusion with the posterior layer of the greater omentum begins about the middle of fetal life, but is often incomplete at birth.

The descending mesocolon, like the ascending, is less frequent in childhood than in after life. Ancel and Cavaillon found it present in about one-sixth of their fetal and newborn material and in over one-third of adults. Like the ascending mesocolon, it is generally a secondary formation and is composed of four layers of peritoneum, but the primary type consisting of two layers is sometimes found.

The sigmoid colon of the infant almost always possesses a long mesentery. The line of attachment of this mesentery has the form of an inverted V, the apex of which is attached to the posterior abdominal wall near the median line, generally about the level of the umbilicus. A large fossa, the recessus intersigmoideus, lies between the two limbs of the line of attachment of the mesentery. This fossa is usually obliterated, from above downward, during childhood by the fusion of the left surface of the mesentery with the posterior abdominal wall.

The chief peculiarity in the pelvic peritoneum in infancy is the great relative depth of the recto-vesical pouch in the male and the utero-vesical pouch in the female. The former extends so far inferiorly that a part of the posterior surface of the prostate receives a peritoneal investment.

The peritoneal relations of the bladder in infancy vary greatly with the distension of that viscus. When the organ is contracted the peritoneum is reflected over it from the anterior abdominal wall about midway between umbilicus and pubis, but when it is fully expanded this point may lie as high as the umbilicus. The plica vesicalis transversa is usually well marked in young children.

The vaginal process of the male and the canal of Nuck (the corresponding structure in the female) are considered in connection with the descent of the testes and with the ovary (p. 361, p. 367). The peritoneal relations of the umbilical region are discussed in the section on the umbilicus (p. 403).

THE VASCULAR SYSTEM

The Fetal Circulation and the Fetal Blood Passages (Fig. 159)

The course of the blood in the late fetus is shown in diagrammatic fashion in Fig. 159. The "pure" or aterial blood from the placental capillaries enters the body through the single umbilical vein. It is carried through the intra-abdominal continuation of this vessel to the liver, where the umbilical vein is joined by the left branch of the portal vein carrying venous blood. The blood from the sinus formed by the union of these veins passes through the ductus venosus (D.V.) which joins with the inferior vena cava either directly or through the left hepatic veins. As the inferior vena cava is returning blood from the capillaries of the lower part of the body, there is a further mixture of venous and arterial blood at the point where it is joined by the ductus venosus. The inferior vena cava enters the posterior portion of the right atrium (auricle). The coronary sinus opening into the right atrium adds a little more venous blood to the main blood stream. The superior vena cava also opens into the right atrium (R.A.), and it carries venous blood from capillaries of the head and superior extremities. The ostium of the inferior vena cava is placed in the posterior part of the right atrium and immediately below and to the right of the foramen ovale, and its valve is so placed that it directs the blood stream towards this foramen. In spite of this anatomical arrangement, however, the blood of the inferior and superior vena cava is completely mixed in the right atrium. Of this fact we have positive evidence based upon experiments of Pohlman[289, 290] on living fetuses of animals.* The mixed blood of the right atrium passes in part into the right ventricle and thence into the pulmonary artery (P.A.). A part of the blood from the main pulmonary artery passes through its right and left branches to the lungs but the greater portion passes through the ductus arteriosus (D.A.) into the descending aorta. The part of the blood of the right atrium which does not flow into the right ventricle passes through the foramen ovale (F.O.) into the left atrium. Here it is joined by a small amount of venous blood which is returned by the pulmonary veins (P.v.) from the capillary bed of the lungs. The blood passes from the left atrium into the left ventricle and thence into the arch of the aorta (Ao.). After supplying the large arteries of the arch the remaining blood passes into the descending aorta where it is joined by the blood from the right ventricle, which comes through the ductus arteriosus (D.A.). The blood passing through the descending aorta supplies the various branches of this vessel and what remains flows into the umbilical arteries and thence to the capillaries of the placenta.

In following this scheme of the fetal circulation it will be noticed: First, but one vessel in the body of the fetus, the umbilical vein, contains strictly arterial blood and this vessel gives off no important branches of supply except to the liver. Second, the blood upon entering the right atrium from the inferior vena cava has already received venous admixtures from three sources—the portal vein, the inferior vena cava, and the hepatic veins. Third, there is a complete mixture of the blood of the superior and inferior venæ cavæ in the right atrium and a further addition of venous blood from the pulmonary veins in the left atrium. Consequently the blood which passes to the upper part of the body from the left atrium has been diluted with venous blood from five main sources since its entrance into the body through the umbilical vein, while the blood which passes from the right atrium through the pulmonary vein has been diluted by venous blood from four main sources.

The amount of blood in the fetal circulation just before birth

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* Pohlmann's experiments were performed upon living pig embryos in which the circulation was rapid and normal. Granules of starch which were injected into the umbilical vein were recovered from both the right and the left ventricles indicating that the blood from the umbilical vein passed through both the right atrio-ventricular orifice and the foramen ovale. Injections into the superior vena cava gave the same results, showing that blood from this source also passed through both the above-mentioned openings. These interesting and conclusive experiments are described in detail in the *Anatomical Record*, vol. iii, No. 2 (Feb., 1909).

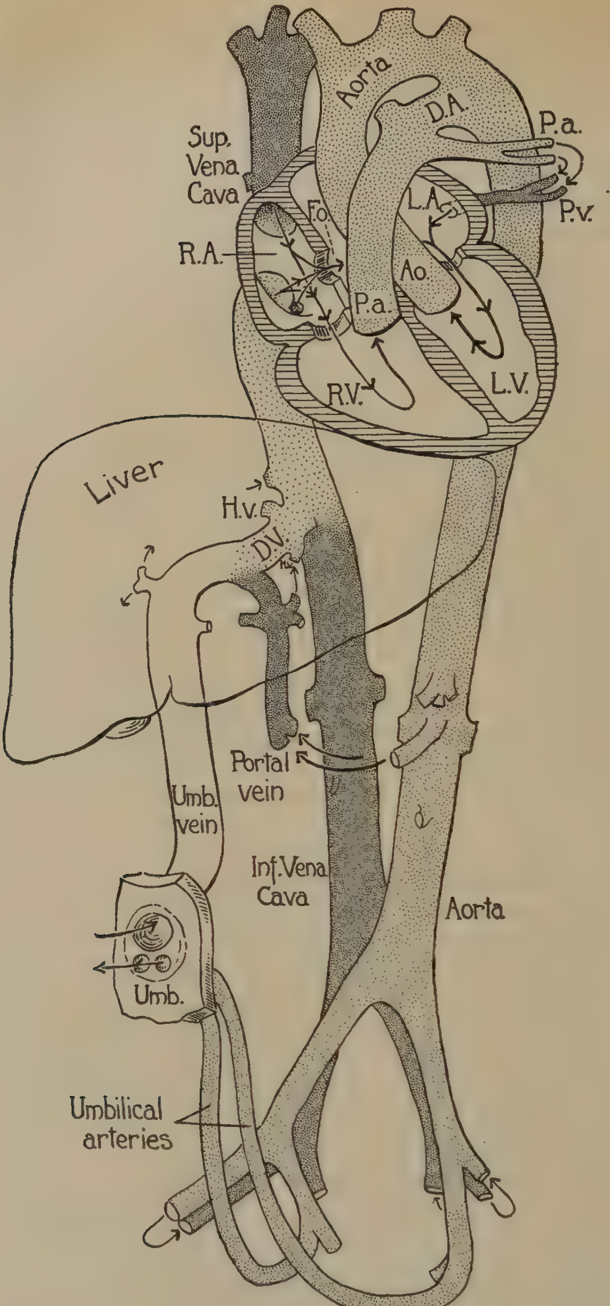

FIG. 159.—Diagram of the fetal circulation. The vessels containing arterial blood are represented in outline only, those containing venous blood in heavy stipple, and those containing mixed blood in light stipple. The course of the blood stream is indicated by arrows. Ao., aorta; D.A., ductus arteriosus; D.V., ductus venosus; F.o., foramen ovale; H.v., hepatic veins; L.A., left atrium (auricle); L.V., left ventricle; P.a., pulmonary artery; P.v., pulmonary vein; R.A., right atrium (auricle); R.V., right ventricle; Umb., umbilicus.

has been estimated to be between 250 and 350 c.c. It forms from one-thirteenth to one-ninth of the total body-weight at birth. About 100 c.c. of this blood is contained in the placental vessels and capillaries.

The change from the fetal to the post-natal type of circulation is brought about at birth by the closure of the fetal blood passages--the umbilical vessels, the ductus venosus, the ductus arteriosus, and the foramen ovale. In the closure of all of these passages we can recognize two processes—the physiological *occlusion* which, with the possible exception of the foramen ovale, takes place immediately after birth, and the anatomical *obliteration* of the lumina which may take place days, months, or even years, after birth. These changes are considered in the following pages along with the detailed descriptions of the fetal blood passages.

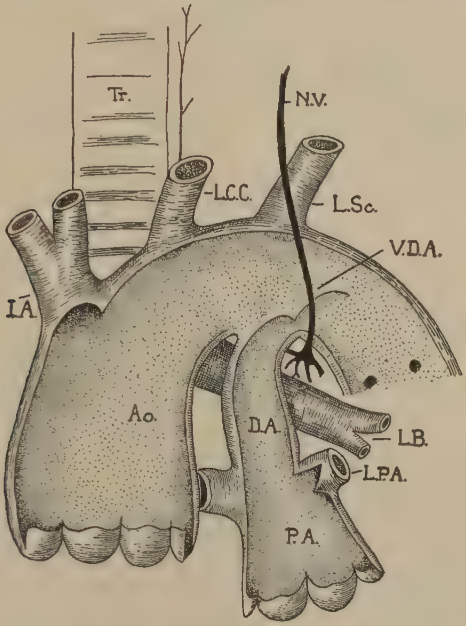

Fig. 160.—Diagram of the arch of the aorta, pulmonary artery and ductus arteriosus in the full-term fetus. Ao., aorta; D.A., ductus arteriosus; I.A., innominate artery; L.B., left bronchus; L.C.C., left common carotid artery; L.P.A., left pulmonary artery; L.Sc., left subclavian artery; N.V., vagus nerve; Tr., trachea; V.D.A., valve of the ductus arteriosus. (After Strassmann.[301])

The Ductus Arteriosus (Figs. 159, 160, 161, 162)

The ductus arteriosus is a short trunk connecting the pulmonary artery with the upper part of the descending aorta. It arises as a direct continuation of the pulmonary artery at the point where that vessel gives off its right and left branches to the lungs, and joins the aorta at its medial border just below the point of origin of the left subclavian artery. The ductus arteriosus joins the aorta at an acute angle (30 to 35°), and the aortic orifice of the ductus is therefore somewhat elongated. Along the upper and right margin of this orifice there is found a more or less prominent flap termed by Strassmann[301] the valve of the ductus arteriosus (Fig. 160). It is, however, a fold between the ductus and the aorta rather than a true valve.

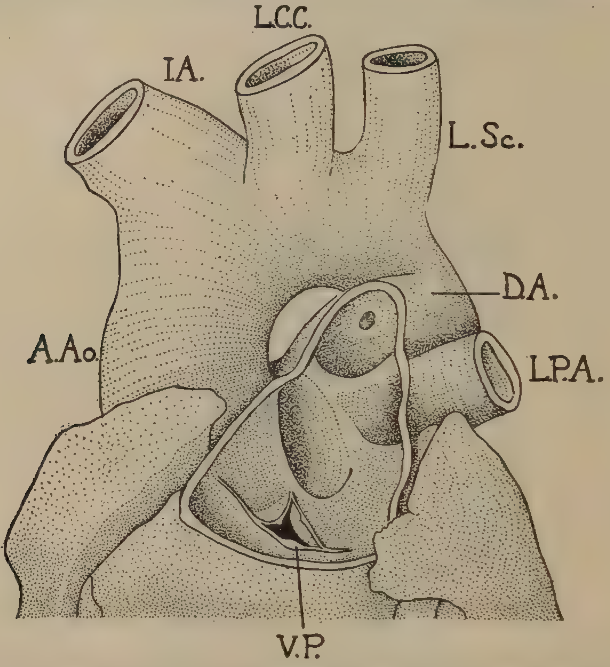

Fig. 161.—Dissection of the pulmonary artery in the newborn child. A.Ao., arch of the aorta; D.A., ductus arteriosus; I.A., innominate artery; L.C.C., left common carotid artery; L.P.A., left pulmonary artery; L.Sc., left subclavian artery; V.P., valves of pulmonary artery. (After Sclavounos.[298])

The length of the ductus arteriosus at birth is extremely variable, but in the majority of cases it is between 8 and 12 mm. The caliber is about 3 mm. During the first three months of post-natal life, according to the observations of Gérard,[282] the ductus lies posterior to the left half of the sternum at the level of the lower part of the first intercostal space or the second rib. It descends during infancy to the level of the second intercostal space. The vessel is entirely extrapericardial in almost all cases. It is in contact with the left bronchus below, and the thymus gland covers it anteriorly. Its relations to the pulmonary arteries and the aorta are shown in Figs. 160, 161.

The finer structure of the ductus does not differ greatly from that of other large arterial trunks. The tunica intima is of considerable thickness. The lamina elastica interna is well marked and the tunica media is of the usual structure although perhaps containing less elastic tissue than does the media of the aorta. There is no definite lamina elastica externa although there are numerous separate elastic fibers in this region. The adventitia blends with the loose connective tissue surrounding the vessel.

Two distinct processes can be recognized in the closure of the ductus arteriosus as in the other fetal blood passages: The lumen of the vessel is occluded immediately after the establishment of respiration but it is not obliterated until a much later time. A great number of theories have been advanced to explain the occlusion of the ductus at birth but, in the opinion of the writer, none are entirely free from legitimate objection. To discuss or even present these theories in any detail would require much more space than is available here but they may be classified into the five general groups as follows:

(*a*) **Theories postulating the compression of the ductus** by structures such as the bronchi when distended with air at the first inspiration; by the left bronchus with the extension of the head during or immediately after birth; or by connective tissue bands extending from the ductus to the diaphragm, which are pulled downward with the descent of the latter. (Most of the hypotheses of this class are of ancient origin and are not considered seriously at the present time.)

(*b*) **Theories Postulating the Reduction of the Lumen of the Ductus through the Change in Position of the Heart at Birth.**—This movement has been interpreted both as stretching the ductus and thus reducing the caliber of its lumen, and as causing a kinking of the vessel with a mechanical obliteration of its cavity.

(*c*) **Theories Postulating a Reduction in the Pressure of the Pulmonary Artery to a Point Equal to or below That of the Aorta with a Consequent Collapse of the Wall of the Ductus.**—Under this heading may be placed the hypothesis of Strassmann,[301] that the increased pressure in the aorta presses the fold of the ductus arteriosus against the orifice of that vessel. Strassmann supports his view by injection experiments. These have been repeated by several other workers, sometimes with negative and sometimes with positive results. Here also may be placed the theory that the collapse of the wall of the vessel occurs at the time when the falling pressure in the pulmonary artery and the rising pressure in the aorta are exactly equal, and a temporary stasis occurs in the ductus.

(*d*) **Theories Postulating the Formation of a Thrombus in the Ductus.**—(These may be thrown out of court, as less than 1 per cent. of the ducts contain a thrombus at autopsy.)

(*e*) **Theories Postulating an Activity in the Wall of the Vessel.**—These may be placed in two groups—those assuming a muscular contraction of the vessel and those assuming an occlusion through the rapid proliferation of connective tissue of the intima.

The reader desiring detailed information on this subject is referred to the papers of Gérard,[282] Strassmann,[301] Schultze,[297] Haberda,[285] Wells[305] and Kirstein.[288]

The obliteration of the ductus is better understood. Even before birth there is a proliferation of the subendothelial tissue of the intima of the vessel. After birth, with the closure of the vessel, the process is accelerated. There is a hyperplasia of the connective tissue and elastic fibers of the intima, and of the inner part of the media as well; the lining endothelium disappears; and the lumen is filled with new connective tissue. This process generally begins in the middle part of the vessel and extends toward its extremities. A small depression in the wall of the descending aorta marks the position of the former ostium of the ductus for some time after obliteration is completed. The published data on the time of the obliteration of the ductus arteriosus have been collated by Norris and Scammon. Less than 1 per cent. of all cases show an obliteration of the lumen in the first ten days after birth. A period of rapid obliteration begins at about two weeks and continues until the end of the third month, at which time about one-half of all cases are obliterated. After this time the percentage of obliterations increases very slowly until the end of the first year when about 95 per cent. of all cases show complete obliteration. After one year the ductus is closed in practically all normal children.

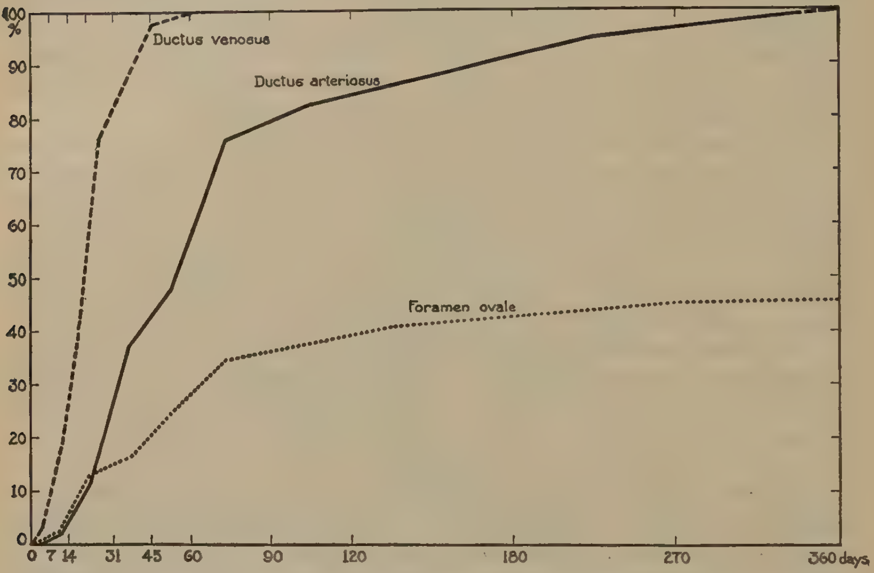

FIG. 162.—A graph illustrating the obliteration (in per cent.) of the fetal blood-passages in the first year. (After Scammon and Norris.[296])

THE DUCTUS VENOSUS (Figs. 159, 162, 163)

The ductus venosus, or duct of Arantius, is a venous trunk which arises from the left branch of the portal vein just opposite the mouth of the umbilical vein, and terminates in the vena cava or more commonly in the left hepatic vein just before that channel joins the inferior vena cava. It lies in the fossa for the ductus venosus between the left and caudate (Spigelian) lobes of the liver. In the newborn it is located practically in the median sagittal line of the body at the level of the ninth and tenth thoracic vertebræ. At the time of birth the ductus venosus is 2 to 3 cm. in length and from 2 to 4 mm. in diameter. In about two-thirds of the cases a small and probably non-functioning valve is found at the portal end of the vessel.

The ductus venosus has the structure of a muscular vein. The thick intima of the vessel is surrounded by a media consisting mainly of circularly arranged muscular fibers mixed with a considerable amount of elastic and some fibrous tissue. The adventitia of the vessel fuses with the surrounding connective tissue of the fossa and contains elastic fibers which have no regular arrangement.

Obliteration of the ductus venosus generally begins in the second week of post-natal life and the lumen is impervious to a probe in most cases by the end of the second month. Obliteration begins at the portal end of the vessel and extends to the caval orifice. Often a funnel-like pocket from the left hepatic vein or vena cava inferior marks the position of the superior opening of the ductus venosus for a long time after birth. A small vein is generally found in the center of the ligament of the ductus venosus in later life. This vessel is not the remains of the ductus venosus, but is a new one which penetrates the connective tissue which fills the lumen of the original vessel. It is connected with the supra-umbilical veins below, and with the peripheral venules which are found in the surrounding connective tissue of the fossa of the ductus venosus.

THE FORAMEN OVALE (Figs. 159, 164, 166, 167)

The foramen ovale is an aperture which connects the posterior part of the right atrium (auricle) with the left atrium throughout fetal life and for a variable period after birth. It is bounded by a rounded ridge, the limbus fossæ ovalis or annulus of Vieussens, and is guarded on the left by a more or less extensive valve. The long axis of the foramen lies in the median line of the body, while the plane of the opening corresponds almost exactly to the frontal plane. Consequently the flow of blood through the foramen is from before backward and the old custom of placing the child on the side to aid in the closure of the valve at birth is without an anatomical basis. At birth the foramen is from 4 to 6 mm. in length and 3 or 4 mm. in breadth.

The valve of the foramen ovale is a membranous flap which is attached to the superior and posterior margins of the left side of the opening. It consists of a fold of endothelium enclosing a core composed of small strands of cardiac muscle separated by delicate connective tissue fibers, and a small amount of elastic tissue.

The foramen ovale is probably functionally closed after the first respiration. With the return of more blood to the left atrium from the pulmonary veins the pressure rises in this chamber and forces the valve against the margins of the foramen. The obliteration of the opening is a much slower process and never takes place in at least a fourth of all cases. Norris and Scammon[296] have collected the published data on the closure of the foramen in childhood. They find that the foramen is obliterated in less than 3 per cent. of all cases in the first two weeks of life. After this period obliteration proceeds more rapidly until the fourth month when approximately

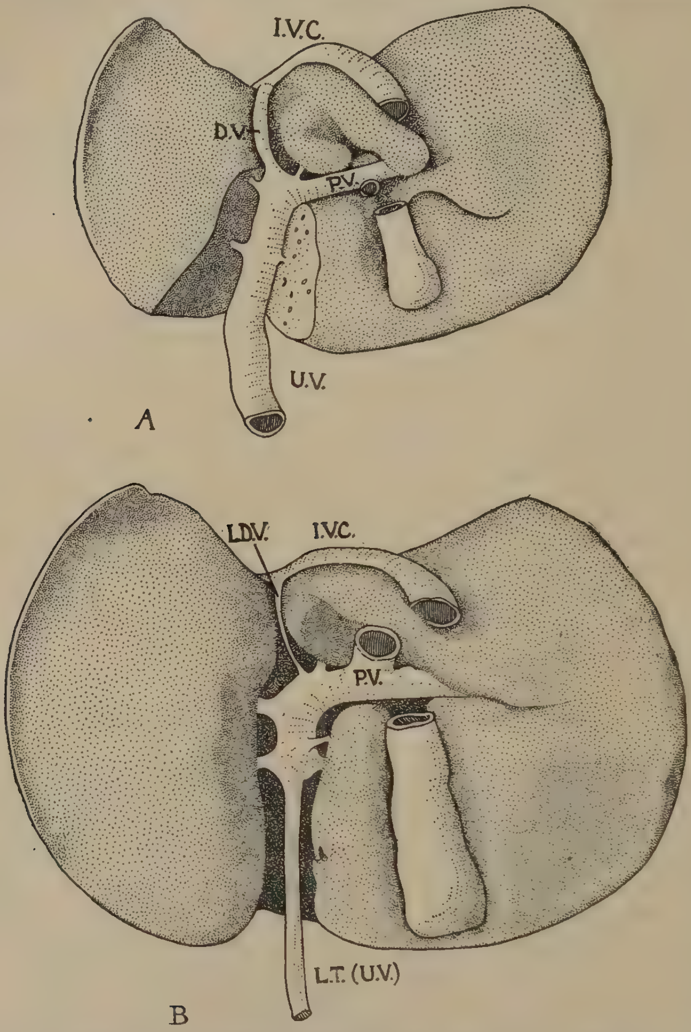

FIG. 163.—Views of the inferior surfaces of the livers of two children (A, newborn; B., one month old) showing the post-natal changes in the umbilical vein and ductus venosus. D.V., ductus venosus; I.V.C., inferior vena cava; L.D.V., ligament of the ductus venosus; P.V., portal vein; L.T., ligamentum teres; U.V., umbilical vein. (After Richter.[295])

one-third of all cases are obliterated. After three months the percentage of obliterations rises very slowly until maturity when about 72 per cent. of all cases show a complete closure of the aperture.

According to Hintze,[286] the obliteration of the foramen is brought about by the irritation caused by the free margin of the valve rubbing against the margin of the aperture. By this irritation the cells of the surface endothelium are destroyed and a proliferation of the underlying connective tissue is induced which results in the fusion of the valve with the margin of the opening.

THE UMBILICAL ARTERIES (Figs. 121, 132, 147, 151, 159, 170)

The umbilical arteries form the direct continuation of the hypogastric (internal iliac) arteries in the full-term fetus. Arising near the upper margin of the lesser pelvis, they run forward beside the ureters and gain the posterior surface of the anterior abdominal wall. They then pass upward on either side of the bladder and urachus, and turning over the lower margin of the umbilical ring enter the umbilical cord. The umbilical arteries give off small branches to the bladder and ureters.

The umbilical arteries, at their origins, have practically the same structure as the other larger arterial trunks, but as they approach the umbilicus their lumina become small and irregular and their walls are greatly thickened. The thickening of the walls of the arteries in the neighborhood of the umbilicus is due mainly to the increase in the number of longitudinal smooth muscle fibers in the inner part of the tunica media. While elastic tissue is abundant in this segment of the vessels the lamina elastica interna is broken up into a number of discrete fibers. As the arteries pass into the mucus connective tissue of the umbilical cord their external coats receive investments of fibrous tissue termed mantel zones. At this level, also, the thickness of the muscular coats is again reduced and the lumina of the vessels are indented by a series of irregular elevations and spirally arranged folds known as the valves of Hoboken.

The post-natal changes which convert the upper segments of the umbilical arteries into the lateral umbilical ligaments cover a considerable period. Immediately the umbilical cord is severed the arteries undergo a contraction so that the flow of blood from their cut ends is generally entirely arrested even though they are not ligated. Thrombi are often formed in the distal ends of the arteries. The actual obliteration of the lumina is brought about by the proliferation of connective tissue in the tunica media and tunica intima of the vessels. Evidences of this proliferation are seen in the walls of the vessels some time before birth. Obliteration proceeds centripetally, and by the close of the second or third month the vessels are usually closed down to the level of the superior vesical artery.

The umbilical arteries usually undergo some longitudinal retraction. This process is apparently an extremely irregular and variable one. Haberda[285] found that it was usually first evident in the third week when the vessels were generally less than 1 cm. below the umbilicus. In children of three months the retraction amounted on the average to 4 or 4.5 cm., and the ends of the arteries lay at the level of the apex of the bladder. The nature of this retraction is still incompletely understood.

THE UMBILICAL VEIN (Figs. 123, 127, 132, 151, 159, 162, 163, 170, 171)

The intra-abdominal portion of the umbilical vein is about 2 cm. in length in the newborn. Arising as the direct extension of the umbilical vein of the funis, it extends upward and a little to the right from the umbilical ring to the porta hepatis where it joins the right branch of the portal vein, forming a sinus of some size. Throughout the greater part of its course it is inclosed between the layers of the falciform ligament. Before joining the portal vein the umbilical trunk gives off several large intrahepatic branches which are distributed directly to the liver tissue.

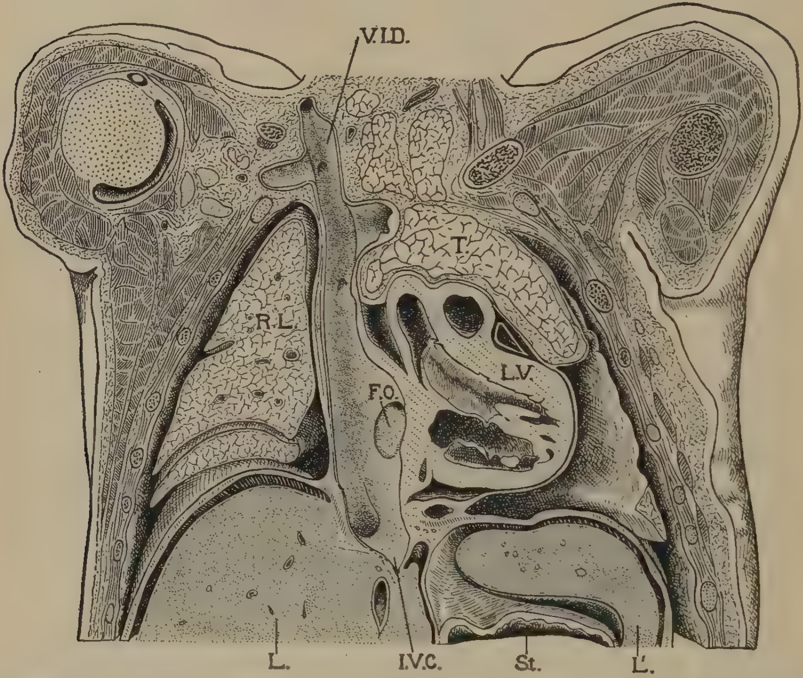

FIG. 164.—Frontal section of the thorax of a premature child of the 7th fetal month. F.o., foramen ovale; L., L', liver; I.V.C., inferior vena cava; L.V., left ventricle; R.L., right lung; St., stomach; T., thymus; V.I.D., right innominate vein.

As compared with the umbilical arteries the vein is thin walled and has a large lumen. The tunica interna is not sharply marked off from the media by an elastic membrane in the intra-abdominal portion of the vein although a definite elastica interna is present at the umbilical ring. The media is composed of bundles of smooth muscle many of which are directed longitudinally and obliquely. These bundles are embedded in a large amount of connective tissue which also contains some elastic fibers. The intra-abdominal part of the vein has an adventitia which also contains elastic tissue.

The post-natal involution of the umbilical vein is somewhat similar to that of the umbilical arteries. The vessel contracts when it is severed, although not as vigorously as do the arteries, and a thrombus is sometimes formed in its lumen. In the immediate vicinity of the umbilicus there is an infiltration of the lumen by connective tissue in the first week, but above this point the cavity remains patent for some time although it is much reduced in size. It is usually about two months before the lumen is obliterated to the level of the lower margin of the liver and small closed cysts may persist long after this time. The vein undergoes some retraction after birth.

Closely associated with the umbilical vein is the set of vessels known as the parumbilical veins. These vessels arise as extensions of the inferior epigastric veins and of the vesical plexus, and after passing upward along the umbilicus enter the falciform ligament. Here they may either run along the ligamentum teres to anastomose with the portal vein, or a vessel may penetrate the ligament and pass upward through its core to join the portal. The vessel which is found in the ligament was at one time regarded as the remains of the umbilical vein but it is now considered a new growth similar to the vein found in the ligament of the ductus venosus. The parumbilical anastomosis is permeable to injection fluids in about two-thirds of all children under four years and in about two-fifths of adults (Haberda[285]). In cases of portal obstruction its elements may develop into vessels of considerable size.

THE HEART (Figs. 122, 123, 160, 164, 165, 166, 167, 168, 169)

The absolute weight of the heart in the full-term newborn child is 20 to 25 gm. This weight is doubled in the first two years of life, tripled in four years, and increased about sixfold by puberty. There is a rapid increase in the heart weight during adolescence, and the heart of the adult weighs from 10 to 13 times that of the newborn. The relative weight of the heart of the newborn is distinctly greater than that of the adult. At birth the heart forms 0.65 to 0.80 per cent. of the total body-weight. With the great increase in body-weight during the first year, this percentage drops rapidly to about 0.45. During the second year the relative heart weight again rises to about 0.50 and this relation obtains, with individual variations, throughout the remainder of childhood and maturity. If the weight of the heart of the newborn be compared to the combined weight of the body and the fetal placenta, it is found that the relation which the organ bears to the tissues which it supplies with blood is little if any greater than in the adult.

According to the statistics of Müller,[291] the weight relations of the atria (auricles) and ventricles change somewhat during childhood. At birth and during the first year the weight of the ventricles is to that of the atria as four or five to one. From the first year on the ventricles grow more rapidly than the atria so that the weight relation between the two is little less than six to one in later childhood and a little more than six to one in adult life.

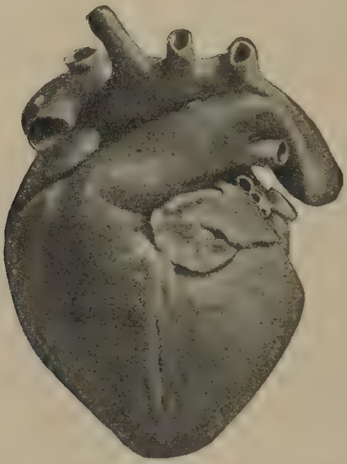

FIG. 165.—Left anterior view of the heart of a full-term newborn child. Natural size.

In the newborn, according to the observations of the same author, the left ventricle weighs about one-fourth more than the right one. But the left grows so rapidly that by the end of the second year it weighs twice as much as the right and from that time on to puberty even a little more. From puberty until the end of the fourth decade the left ventricle is approximately twice the weight of the right one.

The difference in the post-natal development of the right and left ventricles is also illustrated by the changes in thickness of their lateral walls. At birth the average thickness of the lateral walls of the right and left ventricles is approximately equal (about 5 mm.) but by the end of the first month the left one is distinctly the thicker. At the end of the second year the wall of the left ventricle is twice as thick, and by puberty three times as thick as the right.

The dimensions of the heart are very variable in early life and the possibilities of error in their measurement are great. Consequently, in the opinion of the writer at least, no great value can be assigned to the descriptions of Barthez and Rillet[277] and others of minor changes in the dimensional relations of the organ in childhood. In general it may be said that the dimensional increase in the heart in early childhood is not as great as its weight increase or, in other words, the weight increase of the organ is caused by the growth in thickness of its walls rather than by their general expansion. In later childhood the rates of weight and of dimensional increase are more nearly equal. Table 23 below is a summary of the observations of Bizot on this subject.

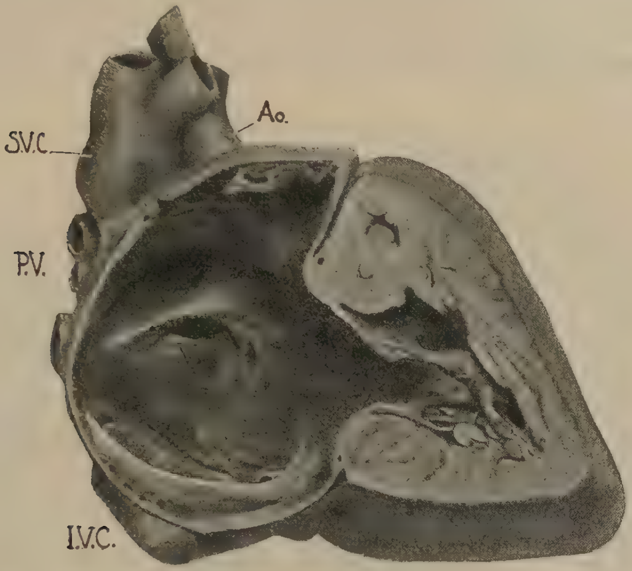

FIG. 166.—Dissection of the heart of a full-term stillborn child, showing the cavities of the left atrium (auricle) and ventricle. Ao., aorta; I.V.C., inferior vena cava; P.V., pulmonary veins; S.V.C., superior vena cava; V., valve of foramen ovale. Twice natural size.

TABLE 23.—THE DIMENSIONS OF THE HEART IN CHILDHOOD (AFTER BIZOT[279])

Age	Length, centimeters	Breadth, centimeters	Thickness, centimeters
Boys			
1 to 4 yrs.	5.14	6.09	2.44
5 to 9 yrs.	7.04	7.44	2.89
10 to 15 yrs.	7.67	8.35	3.16
Girls			
1 to 4 yrs.	5.10	5.83	2.28
5 to 9 yrs.	6.0	6.54	2.55
10 to 15 yrs.	6.59	7.04	2.84

Bardeen[276] has recently investigated the post-natal changes in the weight and volume of the heart by means of teleroentgenography of the living. His findings by this method are somewhat different from the older anatomic ones. According to his calculations, which have been carefully checked by experimental work on cadavers, the weight of the heart in the newborn is about 30 gm. This is increased five-fold in the first six years, ten-fold by puberty and fifteen-fold by the close of the second decade. The volume of the heart, in diastole, is about 35 to 40 c.c. at birth. This is increased about seven-or eightfold in the first decade and from sixteen- to eighteen-fold by the close of the second decade.

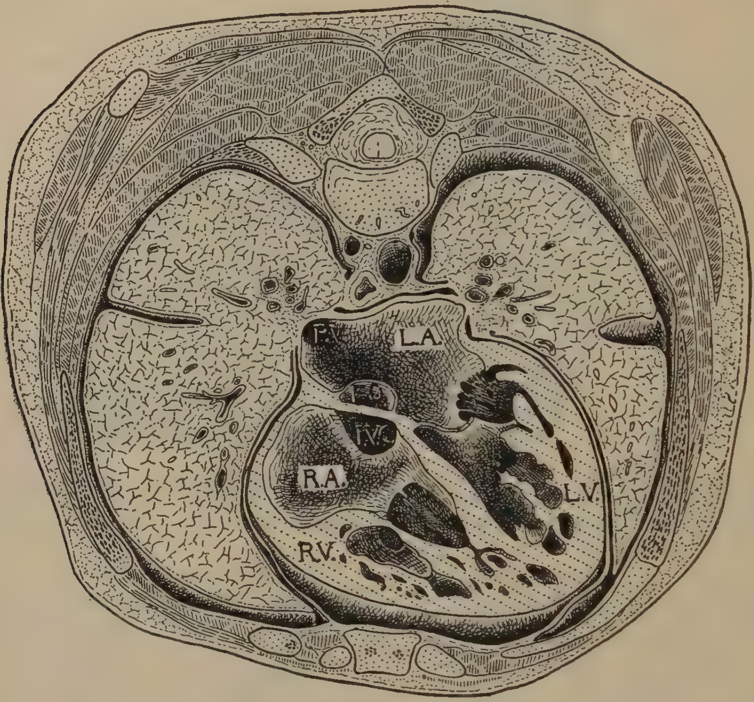

FIG. 167.—Transverse section of the thorax of a newborn child passing through the four chambers of the heart. F.O., foramen ovale; L.A., left atrium (auricle); L.V., left ventricle; I.V.C., inferior vena cava; P.V., pulmonary vein; R.A., right atrium (auricle); R.V., right ventricle. Natural size.

In the full-term infant in which respiration is well established the heart lies practically mid-way between the crown of the head and the pelvic extremity of the trunk.* It lies in front of the vertebral column from the fifth to the eighth or ninth thoracic vertebræ and behind the lower half or more of the sternum and the costal cartilages of the third, fourth, fifth, sixth and sometimes seventh rib on the left side. The axis of the heart is more nearly transverse than in later life. The apex is generally placed in the fifth intercostal space on or just lateral to the left mammillary line. The apex beat is usually found in the fourth intercostal space (von Stark,[300] Troitzky[304]).

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* All anatomic data on the position of the heart in the newborn and young infant are to be accepted with caution. After death, with the body in dorsal decubitus, the large liver tends to fall downward and forward and the delicate diaphragm and associated ligaments are unable to support it. With the displacement of the liver the heart also is pulled downward and the normal relationships are considerably altered.

In the young infant, as in the adult, the greater part of the anterior surface of the heart is formed by the right atrium and right ventricle. The bare area of the heart is relatively larger at birth than in later life, and the greater part of the anterior wall of the right ventricle and sometimes a little of the left ventricle and the right auricular appendage come in contact with the anterior chest wall. As the lungs acquire their full expansion in the first week after birth the extent of the bare area is somewhat reduced. The thymus generally covers the anterior surface of the right atrium except for the auricular appendage and may also extend a little over the base of the right ventricle.

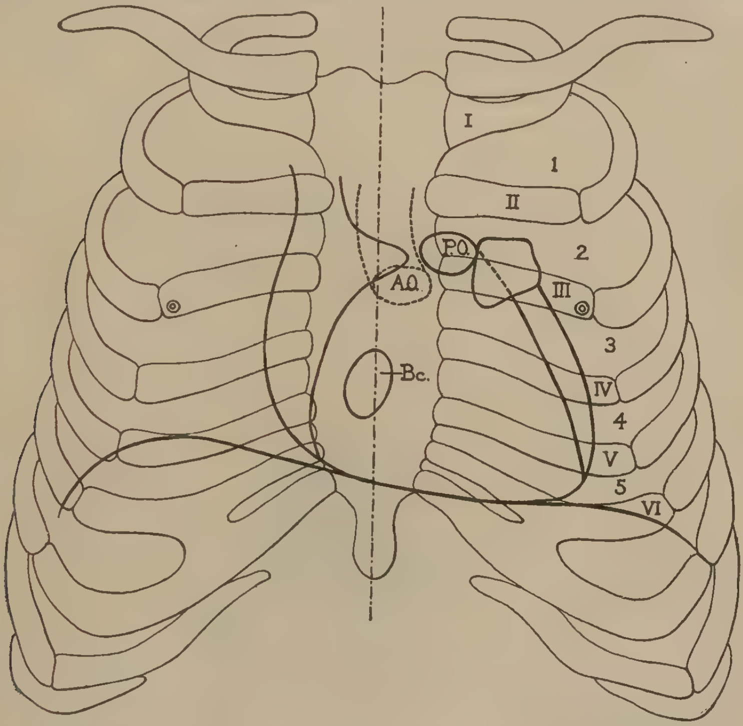

FIG. 168.—Outline of the anterior wall of the thorax of a newborn child showing the position of the heart and some of the cardiac orifices. A.O., aortic orifice; Bc., bicuspid valve; P.O., pulmonary orifice. The ribs are indicated in Roman numerals and the intercostal spaces in Arabic numerals. (After Mettenheimer.[12])

The position of the orifices and valves of the heart in relation to the skeleton in the newborn is shown in Figs. 167, 168. The pulmonary orifice lies at the juncture of the upper part of the third rib with the left margin of the sternum. The aortic orifice lies under the cover of the left half of the sternum at the level of the third rib. Th mitrals or bicuspid valve is a little to the left of the mid-line of the sternum at the level of the third intercostal space and the fourth ribs. Its surfaces lie practically in the frontal plane of the body. The tricuspid valve lies to the right of the mitral and at a slightly lower level (fourth rib, fourth intercostal space and sometimes fifth rib). The foramen ovale lies with its long axis in the median line of the body at the level of the third intercostal space. The valve of the foramen ovale is almost exactly in the frontal plane of the body.

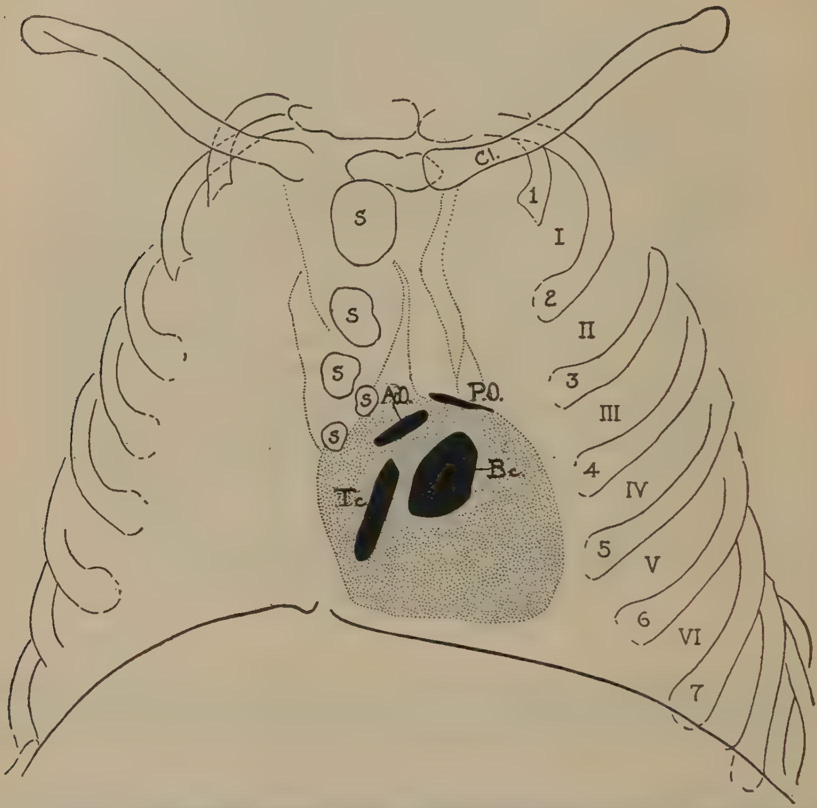

FIG. 169.—An outline drawing of a radiograph of the thorax of a newborn child; Lead plates were inserted in the cardiac orifices and appear as black areas in the figure. The ribs are numbered in Arabic, the intercostal spaces in Roman numerals, A.O., aortic orifice; Bc., bicuspid valve; Cl., clavicle. P.O., pulmonary orifice; S., ossification centers of the sternum; Tc., tricuspid valve. (Modified from Debierre, Looten, Beun, Tramblin, et Lheureux.[230])

We have very few anatomical data regarding the change in position of the heart during childhood, but the results of the methods of physical diagnosis show that the organ is gradually shifted downward and a little to the right. According to the observations of von Stark[300] the apex beat is most commonly found in the fourth intercostal space during the first year of life. From the second to the seventh years it may be in the fourth or the fifth intercostal space or in both. After the seventh year it is almost always in the fifth intercostal space. Until the end of the third year the point of the apex beat is generally lateral to the left mammillary line; in the fourth, fifth, and sixth years it is commonly upon it; and thereafter it is medial to the mammillary line in the majority of cases. The change in the relation of the apex beat to the mammillary line is due both to the movement of the beat medially and to the shifting of the mammæ laterally along with the growth of the anterior chest wall. The conclusions of von Stark are supported by the observations of other and later authors.

The Post-natal Growth of the Blood-vessels

According to the observations of Thoma,[303] the average cross-section area of ascending portion of the arch of the aorta is about 28 square mm. in the newborn and during the first 10 days of post-natal life. This area is doubled in the second year, increased fivefold by five or six years, and increased about tenfold by the middle of the third decade. By this time the body-weight is increased about twenty-fold and the weight of the heart about fifteen-fold. Thus in proportion to the body-weight the lumen of the aorta is twice as great in the newborn as the adult and in proportion to the heart weight nearly one and one-half times as great. The change in these relations begins in infancy but proceeds very slowly during the first period of childhood. It is much more rapid just prior to and during puberty but is not completed until early maturity.

The relation of the caliber of the arch of the aorta to its branches is also greatly modified in childhood. At birth the combined cross-section area of the vessels which conduct blood away from the arch of the aorta (the descending part of the thoracic aorta, innominate artery, left common carotid, and left subclavian arteries and smaller arterial twigs) is not quite equal to that of the vessels which carry blood to the arch (the ascending aorta and ductus arteriosus). But with the closure of the ductus arteriosus the cross-section area of the stream supplying the aortic arch is suddenly reduced to almost half that of the vessels which carry the blood away from the arch. According to the measurements of Thoma, this discrepancy is adjusted, in a large measure, in the first years by the relatively small increase in the caliber of the branches which carry blood away from the arch. However, the cross-section area of the vessels of supply and drainage does not become equal until maturity.

The history of the abdominal aorta is also striking. The cross-section area of this vessel is 16.5 mm. in the newborn and about 80 mm. or five times as much, in the adult. In the meantime, the volume of the part of the body supplied by this vessel increases about thirty-fold. Thus the abdominal aorta is relatively nearly six times larger in section at birth than in early maturity. The closure of the umbilical arteries affects the abdominal aorta much as the amputation of a limb affects its arterial trunk of supply; and during early infancy the vessel actually undergoes a reduction in caliber of about one-fourth. This post-natal reduction is not recovered until the second year. While the caliber of the ascending aorta at birth is considerably less than that of vessels which it supplies the abdominal artery is considerably larger than the combined cross-section area of its branches. This inequality persists to some extent throughout early life and maturity although it is most marked in infancy.

The larger arterial trunks which supply the head and neck and the extremities enlarge to some extent in accordance with the post-natal growth of these parts, but the relation is not a very exact one. Thoma's measurements indicate that the cross-section area of both common carotid arteries is increased about fivefold between birth and the middle of the third decade and the volume of the head and neck also increases about fivefold. On the other hand the left subclavian artery only increases about sevenfold while the volume of the left upper extremity increases nearly sixteen-fold.

The post-natal growth of the arteries which supply the viscera has not been studied in great detail. The table of Nikiforoff[292] quoted below shows some of the differences in the relative blood supply of the larger organs in the newborn and adult.

We know almost nothing of the post-natal growth in length of the arteries. Some observations made many years ago by Schwalbe[299] indicate that the absolute length of the aorta increases about threefold between birth and maturity. The lower part of the abdominal aorta apparently grows a little more than the remainder of the vessel.

TABLE 24.—RELATIVE BLOOD SUPPLY OF ORGANS AT BIRTH AND IN THE ADULT (AFTER NIKIFOROFF[292])

Organ	Relative blood supply*	
	Newborn	Adult
Lungs	0.92	2.25
Kidneys	0.85	3.14
Heart	0.83	3.42
Spleen	0.66	3.00
Digestive tube	0.62	1.25
Liver	0.36	1.88
Brain	0.14	1.56

In fetal life the growth in thickness of the walls of arteries takes place almost entirely in the tunica media and externa, while the interna remains almost unchanged from the fourth fetal month until birth. After birth, however, the tunica interna grows much more rapidly than the tunica media. According to the observations of Aschoff[274, 275] and Gründstein,[284] the media of the common carotid artery is practically doubled between birth and maturity, and the media of the aorta is more than tripled. During the same period the tunica interna of the carotid increases sixfold and that of the aorta more than tenfold. Apparently most of the growth in the media takes place before puberty. Sometimes a considerable growth of the intima is noted as early as five years.

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*Relative blood supply equals total caliber of supplying vessels divided by 1/100 of the weight of the organ.

Although the absolute thickness of the walls of arteries increases considerably during childhood the relative thickness, as compared to the diameter of the lumen of the vessel, is steadily diminished.

The venous system in infancy is less developed, on the whole, than in later life. The statement is made that the volume of the arterial and the venous systems is about equal in infancy while the capacity of the veins is about double that of the arteries in maturity; but I have been unable to find any direct statistical evidence in support of it. The course of the smaller veins is straighter in children than in adults and the valves are relatively more numerous and more efficient. There is said to be a considerable growth of the veins about puberty.

THE UMBILICUS (Figs. 121, 132, 147, 151, 159, 170, 171, 172)

The umbilicus of the full-term newborn is located about 1.5 cm. below the mid-point between the crown of the head and the soles of the feet. With the growth of the inferior extremities it assumes a higher position. At one year it is practically the mid-point between the crown and the sole. In the adult approximately three-fifths of the body length is inferior to the umbilicus.

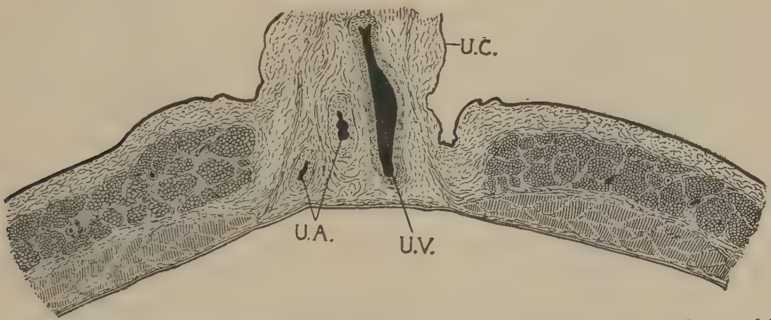

FIG. 170.—A cross section of the umbilicus of a full-term newborn child. U.A., umbilical artery; U.C., umbilical cord; U.V., umbilical vein. One and one-half times natural size.

The umbilicus of the newborn consists of the base or root of the umbilical cord with the vessels contained within it; the umbilical skeleton which is made up of a number of structures of fibrous connective tissue; and the peritoneum which forms its posterior covering. These three main portions will be considered separately.

The fibrous skeleton of the umbilicus is formed mainly from the linea alba. As this structure approaches the umbilical region it becomes considerably wider. In the center of this widened area is a gap or aperture through which the umbilical vessels pass from the cord to the abdominal cavity. This aperture is surrounded by a thickened margin known as the umbilical ring. The umbilical ring is formed by the interlacing of the oblique fibers from the two sides of the linea alba and, like that structure, is composed of white fibrous tissue. The presence of elastic fibers and smooth muscle in the

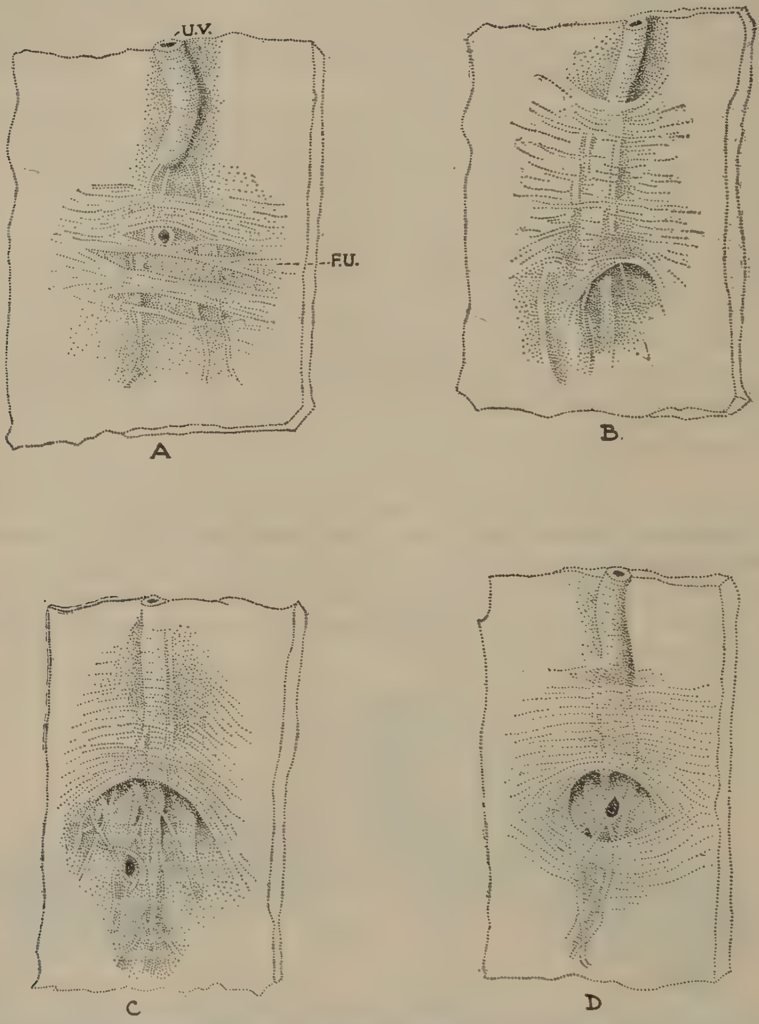

Fig. 171.—Drawings of the peritoneal surface of the umbilical region of four children three to four months old. F.U., umbilical fascia; U.V., umbilical vein. (After Sachs.[315])

umbilical ring, which was described by older writers, has not been confirmed by modern investigation. The umbilical arteries and the fibrous cord which represents the urachus are attached to the lower margin of the ring, while the umbilical vein forms a less firm connection with the upper margin. The umbilical ring is in contact with the superficial fat and fascia anteriorly and with the transversalis fascia posteriorly. The latter is generally thin and inconspicuous in this region but in some cases its fibers are considerably thickened, and form prominent transverse bands which pass across the umbilical region and which are known as the umbilical fascia. The arrangement of these fibers is shown in Fig. 171. As will be seen in this figure, the fascia is generally much better developed over the upper than over the lower half of the umbilical aperture.

The umbilical cord at its fetal end consists of an external covering of simple cuboidal or squamous epithelium which encloses a core of mucus connective tissue, or jelly of Wharton. Imbedded in this jelly are the two umbilical arteries and the single umbilical vein. The epidermis of the abdomen extends out a centimeter or so from the attachment of the cord before passing over into the simple epithelium which covers the remainder of that structure. The jelly of Wharton fuses with the connective tissue of the superficial fascia and projects to a variable degree into the umbilical opening. The two umbilical arteries run side by side to the lower margin of the umbilical ring and, passing over this structure, continue their intra-abdominal course along either side of the urachus. As has been pointed out in the description of the umbilical arteries, the outer parts of their adventitious coats are condensed into a fibrous layer sometimes known as the mantle zone. As the arteries pass over the inferior portion of the umbilical ring the free edges of the mantle zones fuse with this structure. The umbilical vein turns upward as it goes through the umbilical ring and passes over the superior margin of that structure. As it does so it forms a weak fibrous connection with the ring above and a considerably stronger one with the arteries below. The vein, after crossing the superior margin of the umbilical ring, runs a short way in a canal bounded by the posterior surfaces of the recti muscles in front and the transversalis fascia behind; it then passes into the falciform ligament.

The peritoneum posterior to the umbilicus is reflected over the umbilical arteries and vein and the umbilical ring. As a rule its surface is smooth but it may be reflected around the superior and inferior margins of the umbilical fascia or project as a pocket into the space which sometimes intervenes between the vein and the upper or lateral margins of the umbilical ring.

The blood supply of the umbilicus comes from the small arterial springs from the superior vesical arteries below, the inferior epigastric arteries laterally and from the hepatic arteries above. These vessels inosculate posterior to the umbilical ring forming a circle termed by Hyrtl[309] the circulus arteriosus umbilicatus. From this circle small vessels pass through into the connective tissue of the umbilicus and supply it and the covering integument. They form a subcutaneous plexus which extends out on the umbilical cord a little beyond the line of termination of the epithelium of the body-skin. The venous drainage of the umbilicus is mainly through the parumbilical veins.

The lymphatic drainage of the umbilicus has been carefully studied by Cunéo and Marcille[307] whose illustration is reproduced in Fig. 172. Following these authors the lymphatics can be divided into three sets: (1) the cutaneous lymphatics; (2) the lymphatics of the fibrous nucleus; (3) the lymphatics of the umbilical ring proper. The cutaneous lymphatics arise from the skin overlying the umbilical ring and run downward immediately under the integument, to terminate in the superficial inguinal glands. Those of the fibrous nucleus arise around that structure; they pass laterally and, piercing the sheath of the rectus abdominis, reach the deep epigastric artery; they follow the course of the artery to the posterior wall of the rectus sheath where they join with the other lymphatics which drain this region. The lymphatics of the umbilical ring are divided into an anterior and a posterior set. The anterior lymphatics arise around the umbilicus on the anterior surface of the sheath of the rectus. Part of them join with the lymphatics of the nucleus and part join

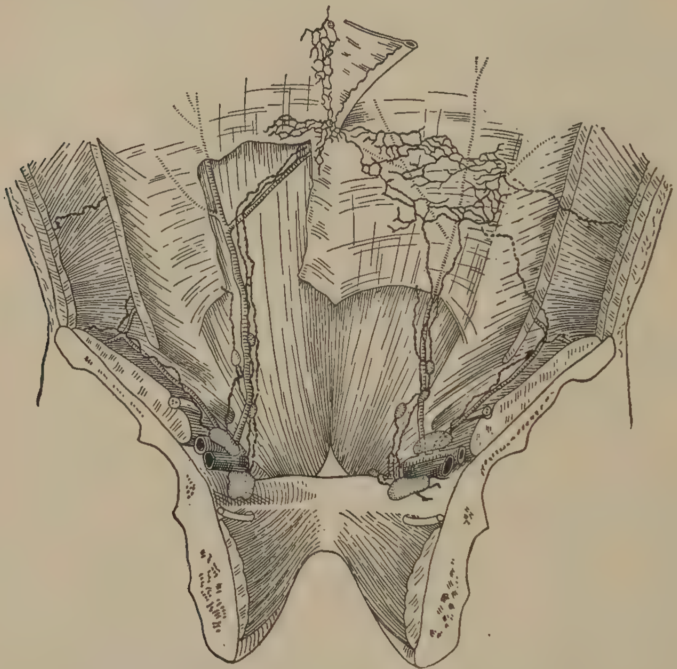

FIG. 172.—Posterior view of the anterior abdominal wall of a newborn child, showing the deep lymphatic drainage of the umbilical region. (After Cunéo et Marcille.[307])

the posterior ones. The posterior lymphatics lie on the posterior surface of the rectus. Part of the trunks draining them join with some of those from the anterior lymphatics and pass to the anterior retro-crural gland or a juxta-aortic gland. Others, joining with the lymphatics of the fibrous nucleus, pass along the deep epigastric artery to terminate in the external iliac glands. Small lymph glands are found in the subperitoneal tissue both above and below the umbilicus in the infant. Both the umbilical arteries and the umbilical vein are supplied with lymphatics which follow them as far as the umbilicus and a centimeter or so into the cord. The lymphatics of the vein join those of the portal fissure of the liver while those of the arteries communicate with those of the bladder.

After the ligation of the umbilical cord at birth the stump which remains undergoes desiccation and at the close of a few days is cast off as a foreign body. In the meantime, the skin covering the margin of the umbilical ring begins to fold in at the base of the stump, first at its inferior margin and later around its entire circumference. There is thus formed a crater-like depression to the floor of which is attached the mummified remains of the umbilical cord. When the stump of the cord is finally detached there is exposed a small area covered with granulation tissue and containing the obliterated ends of the umbilical vessels. The skin lining the sides of the umbilical funnel quickly grows over this area and completes the cutaneous umbilicus. At the same time the delicate connective tissue which formerly constituted the root of the umbilical cord is rapidly converted into a dense fibrous mass which remains throughout life as the nucleus of the umbilicus. These changes are usually completed by the end of the third week of life.

The causes of the umbilication of the ring are still obscure. The traction of the contracting and retracting umbilical vessels; the supposed sphincter-like action of the umbilical ring; and the pull of the umbilical arteries due to the change in the shape of the abdomen and the position of the body after birth have been suggested as factors in the process. Meyer[312] has recently contributed an excellent discussion of this problem.

The changes in the umbilical vessels after birth have already been considered.

THE LYMPHOID ORGANS (INCLUDING THE THYMUS)

The Lymphatic Glands

Our knowledge of the anatomy of the lymphatic glands in children, particularly of their finer structure and growth, is still extremely fragmentary. At birth the size of these structures varies from microscopic proportions to that of a large pea. They are of pinkish color, being almost entirely free from the surrounding fat which gives them the yellowish shade seen in later life. The connective tissue capsule and trabeculæ which form the supporting framework are very thin and delicate, and the reticular tissue network is composed of cells richer in protoplasm than those of the adult gland. The lymphoid tissue is very abundant and is arranged peripherally in large, rather indistinct nodules which are less numerous than in the adult. Germinal centers are hardly ever seen in the lymph-glands of the newborn. According to Gundobin,[7] they first appear in the second month of postnatal life and do not stand out plainly until the third year. Although present and of considerable diameter, the peripheral lymph-sinuses are often inconspicuous in the newborn and adult, because of the number of lymphocytes which they contain.

The amount of lymphoid tissue segregated in the lymph-nodes is considerable at birth, increases steadily during childhood, and after puberty undergoes at least a relative reduction. The increase during childhood is due in part to the growth of the glands already present at birth and in part to the formation of new glands. Wullenweber,[334] who has made the most careful study we possess on this subject, found that the average weight of the individual mesenterial lymph-gland increased nearly 20 times between birth and maturity while their number increased about three times. The number of palpable superficial glands at different ages has been studied in a large series of cases by Dietrich[318] and his results are given in tabular form below. Certain glands, such as the supra and infra-umbilical and the anterior tibial glands, generally disappear entirely after puberty.

TABLE 25.—THE PALPABLE SUPERFICIAL LYMPH-GLANDS AT DIFFERENT AGES (AFTER DIETRICH[318])

		Gland groups				
		Occipital	Cervical	Axillary	Cubital	Inguinal
Percentage of cases in which glands are palpable	Children to 12 years....	5.4	100.0	92.7	96.3	100.0
	Youths 13 to 20 years...	5.3	81.9	69.1	77.4	91.4
	Adults 21 and over.....	0.68	74.7	68.9	81.7	92.0
Average number of glands palpable in each group	Children to 12 years....	1–2	7–8	3–4	circa 6	8–9
	Youths 13 to 20 years...	1	3	2	2	6–7
	Adults 21 and over.....	1	2–3	1–2	1–2	7

THE SPLEEN (Figs. 127, 128, 129, 132, 147, 156, 173)

The weight and dimensions of the spleen are very variable at birth as they are indeed during all periods of life. Omitting all cases of proved or suspected lues congenita, the writer found an average spleen-weight of 13.5 gm. in a series of 150 full-term newborn children. The weight of the organ at birth may vary, however, from 5 to 20 gm. even in cases where lues is rigidly excluded. The spleen approximately doubles in weight during the first year of life, and is tripled during the third; thereafter the growth is slower. The total weight increase from birth to maturity is about twelve-fold, or something over half that of the total gain in body-weight. The dimensional growth of the spleen is shown in Table 26 which is a summary of an extensive series of cases collated by Stricker.[333] All cases of gastro-enteritis have been excluded from this series.

TABLE 26.—THE DIMENSIONS OF THE SPLEEN IN CHILDHOOD (Summarized From Stricker[333])

Age	Number of cases	Average length, centimeters	Average breadth, centimeters	Average thickness, centimeters
Newborn under 3000 gm. body-weight	141	4.0	2.5	1.0
Newborn 3000 gm. and over body-weight	174	5.0	3.0	1.0
1 to 6 months	141	5.6	3.2	1.5
6 to 12 months	32	6.7	3.9	1.6
1 to 2 years	44	6.8	3.7	1.7
2 to 3 years	30	7.2	4.1	1.7
3 to 6 years	74	8.0	4.6	2.0
6 to 9 years	40	8.4	5.0	2.5
9 to 12 years	38	9.7	5.9	2.2
12 to 15 years	26	11.8	6.5	2.6
15 to 21 years	97	12.1	8.2	3.0

The relations of the spleen in the newborn and young infant differ considerably from those observed in later life. In the newborn the long axis of the organ is generally vertical or oblique. The superior margin, according to the studies of Fleury,[320] lies most commonly at the level of the eighth rib although it may be as high as the seventh or as low as the ninth. The lower margin generally lies at the level of the eleventh rib although it may be as high as the tenth or as low as the umbilical line. Macè[327] found that the spleen was palpable under the costal margin in 6 per cent. of healthy newborn children of non-syphilitic mothers. The spleen of the young infant has two general surfaces: a lateral one which is in contact with the diaphragm and, in many cases, with the margin of the left lobe of the liver; and a medial one which may be subdivided into colic, gastric and suprarenal surfaces in contact with these organs. The form and positions of the contact areas of the medial surfaces of the spleen are shown in Fig. 173. The pancreas is in contact with the hilus of the spleen in the infant as in the adult. The organ is entirely prepleural in position (Jackson[10]). The change from the relations described to those of the adult are brought about rapidly during the early part of childhood through the *relative* decrease in the size of the liver and the left suprarenal. As the size of the latter organ remains practically stationary in the first two years of post-natal life, the kidney gradually replaces the suprarenal in its relation to the posterior part of the medial surface of the spleen. As the stomach increases in size it apparently displaces the spleen to the left but does not press it downward in the abdominal cavity.

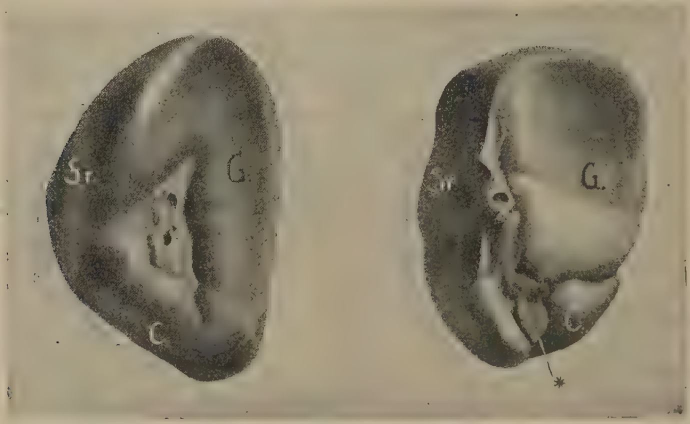

FIG. 173.—Drawings of the visceral surfaces of the spleens of two newborn children. C., colic surface; G., gastric surface; Sr., suprarenal surface; *accessory spleen. Natural size.

The modern methods of hematology have not been applied to the study of the spleen in infancy and our information regarding the finer structure of the organ at this time is most limited. Splenic, or Malpighian, corpuscles are developed in the latter half of fetal life. At birth they have much the same general structure as in later life. They form a larger proportion of the mass of the spleen and are placed closer together. The reticular fibers of the spleen do not differ greatly from those of the adult except in size. They continue to increase in thickness until puberty (Matsui[328]). Elastic fibers are present in the spleen as early as the sixth fetal month.

Accessory spleens are very common in young children. Jolly[325] found them in 25 per cent. of a series of 80 children less than seven years old and Sassuchin (quoted by Gundobin[7]) observed them in 23 cases in a series of 153 autopsies of children under 10 years. He found them much more common in newborn infants and sucklings than in older children.

THE THYMUS (Figs. 164, 174, 175, 176, 177, 178, 179)

Practically all observers who have examined large series of material find that the average weight of the thymus at birth is between 12 and 14 gm. In a series of 205 cases collected by the writer from personal observation and from the literature, the average weight was 13.2 gm. This series was limited to stillborn children and infants who died within 48 hours after birth; and no cases were included in which the body-weight was less than 2,700 gm. or the body-length less than 48 cm.

While the average weight of the thymus is about the same in all extensive series of cases the individual variations are very great. In the writer's series, the minimum weight was less than 2 gm. and the maximum weight was 28 gm. A frequency curve, based on this series, is shown in Fig. 174. As will be seen, the curve as a whole is a remarkably smooth one and it would be extremely difficult to draw a sharp line between the normal and abnormal cases on the basis of weight alone.

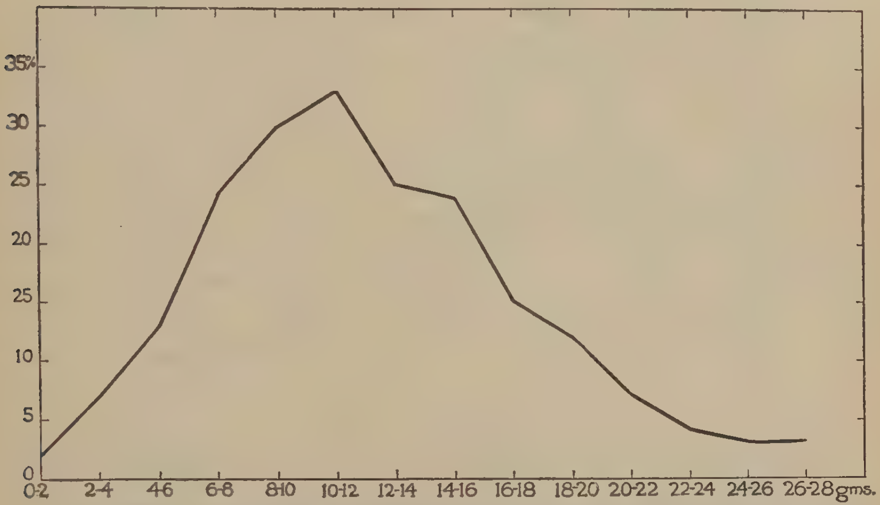

FIG. 174.—A percentage frequency graph showing the variation in weight of the thymus in full-term newborn children. Based on observations on 205 infants 48 cm. or more in length, or 2750 grams or more in weight which were still-born or died within 48 hours after birth.

The subject of the post-natal growth and involution of the thymus, which was in a state of great confusion for years, has been cleared up by the studies of Hammar.[322] He found that the weight of the gland increases steadily from birth to puberty; and then, as a rule, decreases slowly until the later years of life. The birth weight is doubled in the second lustrum and practically tripled in the third. Hammar's results are in conflict with the older view that the involution of the body began in infancy or early childhood, but their accuracy cannot be gainsaid. They are based upon abundant material which was selected with the greatest care both as to the previous history and the general bodily condition of the cases. The findings of von Sury,[332] and of Ronconi,[331] as well as the older work of Friedleben,[321] on selected cases, are confirmatory of Hammar's views. The lower weights which are quoted in most of the earlier literature are probably mainly from cases which had undergone accidental or hunger involution. The experimental studies of Jonson[326] show that this process takes place very rapidly and that a large part of the thymus weight may be lost before the body-weight is seriously affected. Hammar's results are shown in numerical form in

Table 27. Figure 175 is a graph showing the weight changes in the thymus during the first three decades. The curve in solid line is based upon Hammar's cases and the curve in broken line on Ronconi's Italian material. These two curves agree essentially although Ronconi's weights are consistently lower than those of Hammar—a difference which may be racial.

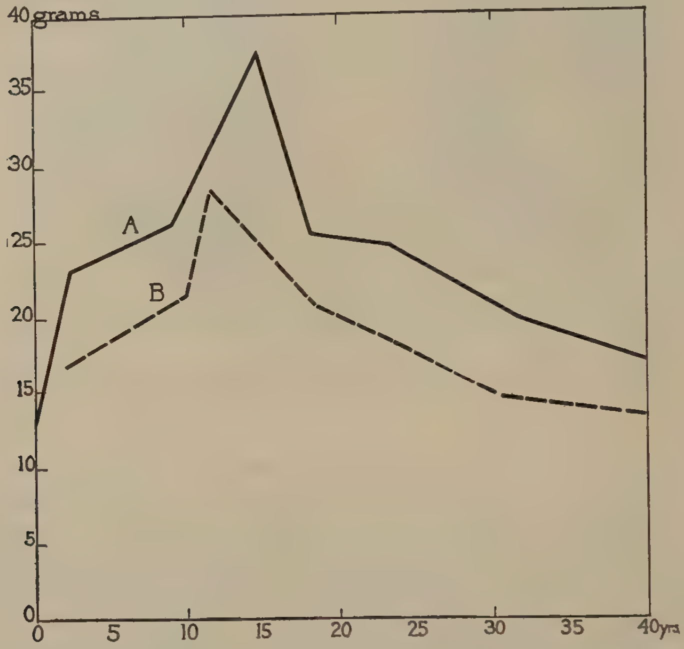

Fig. 175.—A graph illustrating the weight changes in the thymus during childhood and early maturity. Curve 'A' based upon the data of Hammar; curve 'B' based upon the data of Ronconi.

According to Hammar, the thymus forms 0.42 per cent. of the body-weight at birth. The relative weight drops to 0.12 per cent. in later childhood, 0.09 per cent. in adolescence and 0.05 to 0.03 per cent. in maturity.

The dimensions of the thymus are always quite variable. The series of observations by von Sury, which is quoted in Table 28, is among the most extensive on the subject and is based on selected cases. As will be seen from this table, the thymus becomes both relatively and absolutely longer in childhood, while breadth and thickness undergo but little absolute increase and are relatively reduced.

The form of the thymus is very inconstant, and any simple description of it will apply only to certain selected specimens. It is commonly described as consisting of two lateral lobes. Coplin[316] has recently proposed a classification of the forms of the thymus which is more satisfactory. He recognizes four main types as follows: (*a*) the unilobar type, of which he found but one specimen in a series of over

TABLE 27.—THE POST-NATAL WEIGHT-CHANGES OF THE THYMUS (AFTER HAMMAR[322])

Age, years	Average age, years	Number of cases	Weight in grams			Per cent. of body-weight	Weight of parenchyma	Per cent. of parenchyma as compared to total weight of gland	Weight of cortex, grams	Weight of medulla, grams
			Average	Minimum	Maximum					
Newborn	.....	23	13.26	7.6	25.88	0.42	12.33	93.0	9.69	2.63
1 to 5	2.35	23	22.98	8.5	49.0	0.22	19.26	83.8	13.63	5.63
6 to 10	9.0	5	26.1	20.0	30.0	0.12	22.08	84.6	12.71	9.37
11 to 15	14.75	4	37.52	20.0	52.0	0.09	25.18	67.1	11.63	12.08
16 to 20	18.2	10	25.58	15.2	47.0	0.05	12.71	49.7	2.12	10.46
21 to 25	23.3	15	24.73	7.3	45.0	0.04	4.95	20.0	0.74	4.20
26 to 35	31.8	15	19.87	4.29	30.0	0.03	3.87	19.5	0.89	2.98
36 to 45	42.1	12	16.27	8.2	28.0	0.03	2.89	17.8	1.55	1.33
46 to 55	52.0	7	12.85	2.5	21.0	0.02	1.48	11.5		
56 to 65	62.0	6	16.08	5.6	30.0	0.03	0.73	4.5		
66 to 75	69.25	4	6.0	3.0	8.0	0.03	0.03	0.5		

500. (*b*) The bilobar type which is more common than the unilobar but is not the most frequent one (this is the type which is usually described as the "normal" one). (*c*) The trilobar type in which the gland is composed of two inferior and lateral masses and a median and superior one. Coplin finds this form the most common. (*d*) The conglomerate type in which no definite lobation is apparent. Some examples of the variable form of the body in the newborn are shown in Fig. 176. Noback[329] finds the bilobar type the most common (39462 cases examined).

TABLE 28.—THE AVERAGE WEIGHT AND DIMENSIONS OF THE THYMUS IN CHILDHOOD (AFTER V. SURY[332])

Age	Number of cases	Average weight, grams	Average dimensions, centimeters		
			Length	Breadth	Thickness
Birth	21	14.1	6.05	5.5	1.1
1st mo	10	15.9	5.8	5.2	1.4
2nd to 9th mo	27	24.3	7.4	5.6	1.5
9th mo. to 2 yrs	12	23.2	7.5	5.7	1.4
2 to 14 yrs	12	25.8	9.7	6.1	1.3

The relations of the thymus vary with its size. The description which follows is of the average gland. The relations of the thoracic and cervical portions of the body may be considered separately.

The thoracic portion of the thymus, in the child immediately after birth, is covered by the upper half of the sternum and generally by the first three costal cartilages. Its vertical extent corresponds to the firxt four thoracic vertebræ. The anterior surface of the gland is in contact medially with the endothoracic fascia covering the hinder surface of the sternum and with the internal mammary vessels. Laterally it lies behind the medial borders of the pleural sacs and in contact with the margins of the lungs. The posterior surface rests upon the great vessels of the superior mediastinum, the upper part of the thoracic portion of the trachea, and the upper part of the anterior surface of the heart. The relation of the posterior surface of the thymus to the left innominate vein is a very intimate one, and sometimes the vessel is partially imbedded in the thymus substance. As Hammar has pointed out, the thickest part of the gland lies immediately above the base of the heart and not at the superior thoracic aperture where the gland is supposed to exert pressure in cases of thymic enlargement.

The cervical portion of the gland is usually a tongue-like process which may lie in the mid-line or to one side. It may extend upward to the lower margin of the thyroid. It rests on the anterior surface of the trachea or the carotid sheath, and is covered by the anterior layer of the deep cervical fascia and the infrahyoid muscles. The cervical extension is sometimes entirely lacking or it may be represented by a fibrous band connecting the main mass of the thymus and the thyroid.

The changes in the form and relations of the thymus in the neonatal period have been recently worked out in detail by Noback. He finds that the change from the broad type of gland characteristic of the fetus to the elongated type found in the young infant bears a direct relation to the establishment of respiration, and is dependent on the expansion of the lungs. The organ is compressed from side to side by the medial surfaces of the expanding lungs, and is also compressed anteroposteriorly by the anterior borders of these structures as they become thickened with the establishment of respiration. After respiration is established the thymus usually extends more inferiorly passing over the right ventricle.

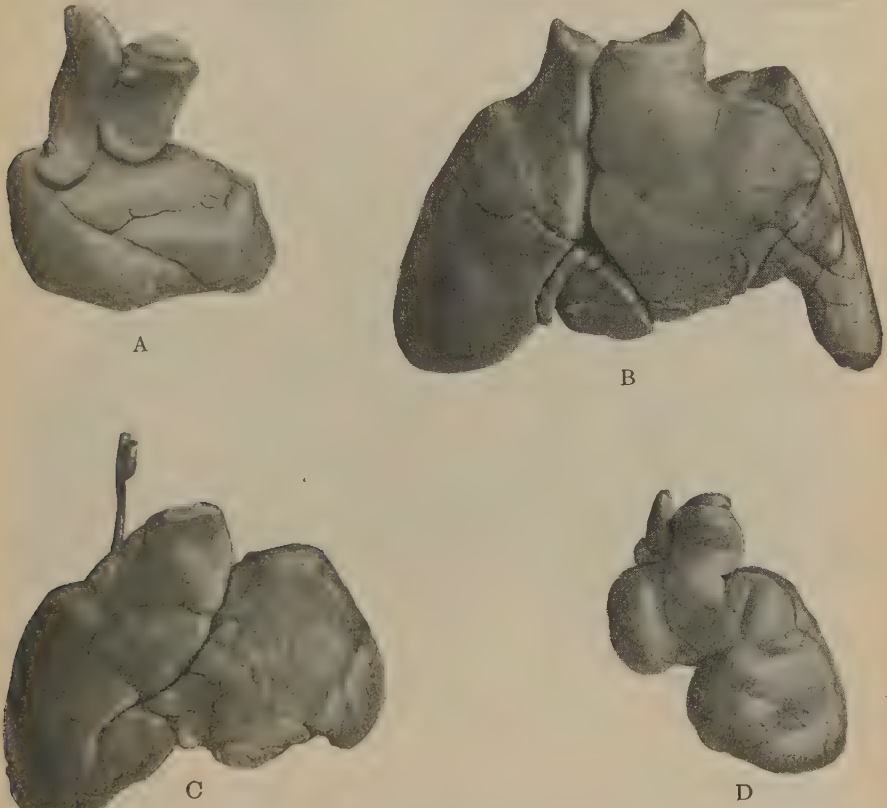

FIG. 176.—Anterior views of the thymi of four full-term newborn children. The specimens are from material hardened in situ. Natural size.

The thymus gradually becomes longer and narrower in infancy and childhood, but its lateral margins generally still remain in contact or under the cover of the medial edges of the lungs. As the gland elongates it extends downward over the greater part of the anterior surface, and the cervical portion becomes less noticeable.

The histological picture of the thymus changes greatly with age. In the newborn the parenchyma is very abundant, forming, according to Hammar, 93 per cent. of the gland. The lobules are large and angular, and are separated by very narrow trabeculæ of delicate connective tissue. The cortex forms by far the larger proportion of the parenchyma and shows very little division into secondary nodules. Thymic or Hassel's corpuscles are numerous but are not as abundant as in later life.

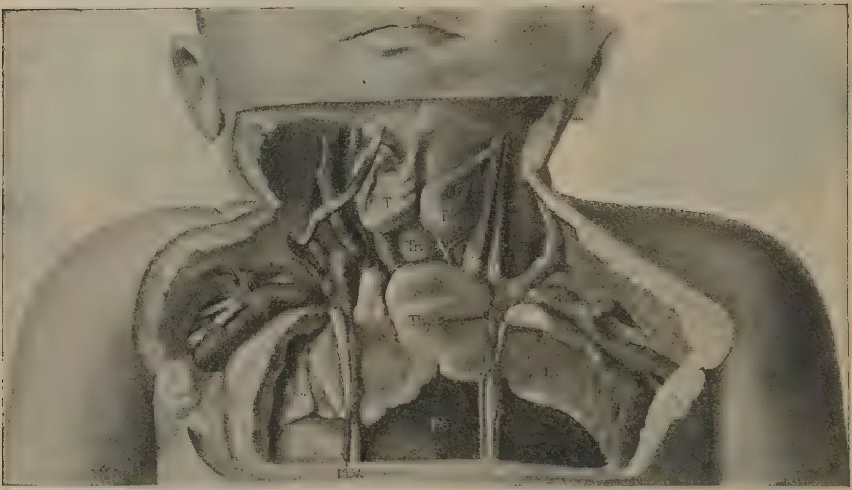

Fig. 177.—A dissection of the neck and superior mediastinum of a postmature, newborn, female child weighing over 4000 grams. A.v., axillary vein; C., left common carotid artery; J., internal jugular vein; L., lung; M.V., internal mammary vessels; O., omohyoid muscle; Pc., pericardium; T., thyroid gland; Thy., thymus gland; Tr., trachea. Three-fourths natural size.

During childhood all parts of the thymus grow rapidly, but the relative increase of the interlobular connective is greater than that of the parenchyma. The medullary portion of the lobules also increases more than the cortical part, and the latter is partially subdivided by the ingrowth of narrow secondary connective tissue septa.

At and after puberty the connective tissue framework of the gland becomes still more noticeable, the interlobular septa are much thicker, and the secondary septa which mark off the nodules of the cortex are widened. The medulla forms the major part of the parenchyma and the cortex is broken up into a series of rounded nodules. The thymic corpuscles are considerably increased.

In early maturity the interstitial connective tissue forms as much or more of the gland than the parenchyma and the cortical nodules of the lobules are reduced to rounded projections from the medulla.

Fat cells are sometimes found in the thymus at birth but they grow very little until early maturity when there is a marked increase in the amount of adipose tissue in the septa.

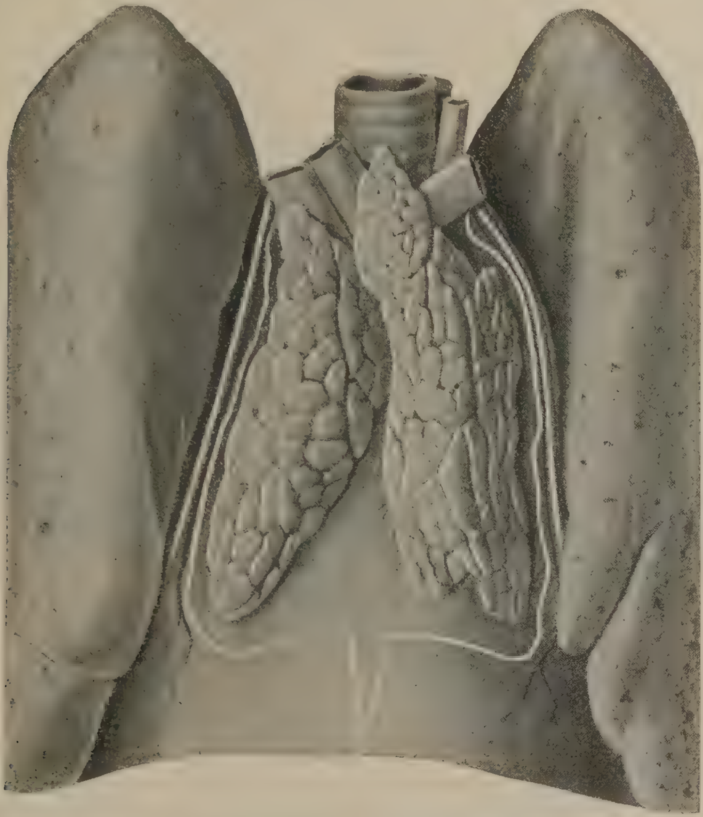

Fig. 178.—Thymus of a girl 14 years old. (After Sobotta in Bardeleben's Handb. d. Anat. d. Menschen. Bd. VI.)

Accessory masses of thymic tissue are not unusual in childhood. They are sometimes found in the immediate region of the main body of the gland, but are more common in the cervical region in the neighborhood of the thyroid or even in the carotid triangles.

THE CENTRAL NERVOUS SYSTEM AND THE ORGANS OF SPECIAL SENSE

The Brain (Figs. 133, 135, 180, 181, 182,)

The weight of the brain in the full-term Caucasian newborn varies from 300 to 400 gm. and averages about 350 gm. The variation in the weight of the brain at birth, while seemingly great, is relatively less than in any other organ of the body with the possible exception of the eyeball. It is dependent to some degree on bodily development and to a lesser one on sex, the brains of newborn males being slightly heavier absolutely than those of females. The total weight of the brain increases from three and one-half to four times between birth and maturity. The growth of the brain may be divided into three periods. From birth to the end of the first year the growth is very rapid and the brain increases approximately two and one-half times in weight. From the end of the first to the middle of the fifth year growth continues at a reduced although still a rapid rate, and by the end of this period the brain weighs about three times as much as at birth. After this time brain growth is very slow indeed and the adult weight is acquired by the end of the fifteenth year. Putting this statement in another form the brain accomplishes about one-third of its total absolute post-natal growth in the first year, one-third between one and two and one-quarter years, and the final third between two and one-quarter years and fifteen years. There is probably little if any increase in brain weight after 15 years, and in some cases the average adult brain weight is acquired by the seventh year. A period of increased brain growth at puberty has been described, but the writer's examination of most of the published data on brain weights in children fails to confirm this observation. Throughout childhood the brains of boys average absolutely heavier than those of girls. There is, however, no evidence of much difference in the relative brain weights in the two sexes.

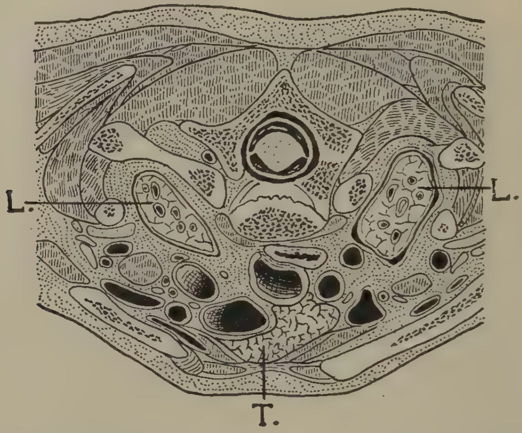

Fig. 179.—Transverse section of the superior aperture of the thorax of a girl three years old, showing the position of the thymus. L., lung; T., thymus. (After Dwight.[4])

The relative weight of the brain as compared to that of the body is very high at birth, being from 1:8 to 1:10. In the adult, according to Ziehen, the relation is 1:42 in males and 1:40 in females.

According to the data of Pfeister,[351] the weight of the cerebrum at birth is from 305 to 345 gm. At this time it forms about 93 per cent. of the entire brain weight. The total post-natal weight increase of the cerebrum amounts to 840 gm. or even more. Nearly one-third of this increase takes place in the first ninemonths, and nearly two-thirds in the first two years. The frontal lobes grow more than do the other parts of the cerebrum. The relation of the grey matter of the cortex to the white matter of the medulla has been determined by Anton[335] and Jaeger[345] by means of the polar planimeter. The former found that the relation of the volume of the cortex to the volume of the medulla in the child was as 1:2 in the frontal lobe and as 1:3 in the occipital lobe; in the adult the corresponding relations were 4:5 in the frontal lobe and 1:2 in the occipital lobe. Jaeger's results in general support those of Anton. Aresu,[336] on the other hand, using a more elaborate method, found that the cortical grey matter formed 58 per cent. of the weight of the entire cerebrum in an infant one year and four months old; 67 and 43 per cent. respectively in two children of two years; 77 per cent. in a child of four years and 67 and 64 per cent. respectively in two young adults. There have been no extensive studies on the growth of the basal ganglia of the cerebrum, but Franceschi (quoted by Donaldson[341]) found that these masses weighed 24 to 25 gm. in two children under five years of age as compared with about 41 gm. in the adult.

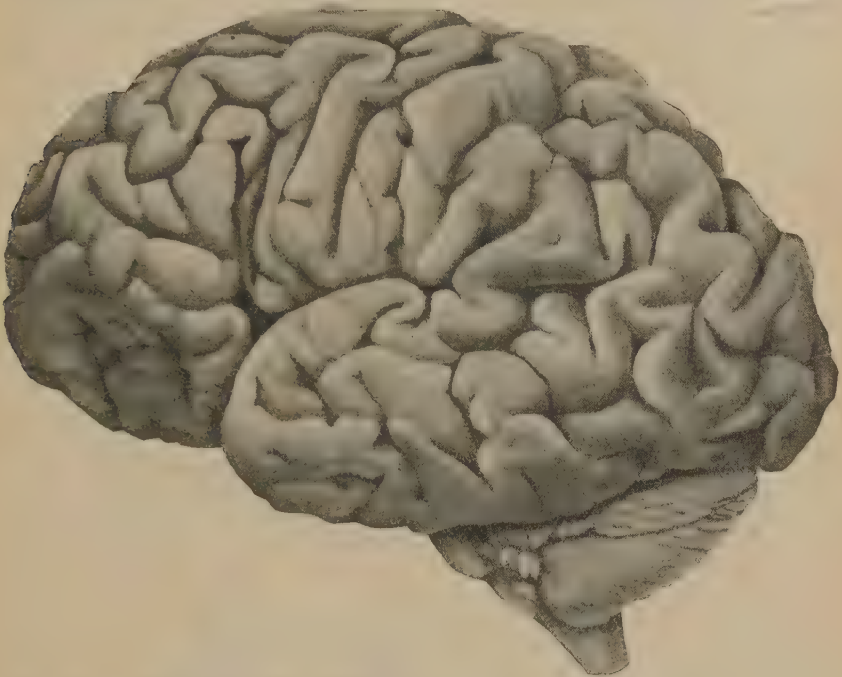

FIG. 180.—Left lateral view of the brain of a male, newborn child 53 cm. long. Natural size. (After Retzius.[353])

The cerebellum weighs from 18 to 20 gm. at birth, thus forming about 5 or 6 per cent. of the entire brain weight. During the entire period of post-natal growth it increases about seven-fold or nearly twice as much as the brain as a whole. One-third of this growth is accomplished in the first six months, and two-thirds in the first year and three-quarters after birth (Pfeister[351]). During this period the relative weight as compared with that of the whole brain rises from 5 or 6 to 10 or 11 per cent., which is the ratio in the adult.

The brain stem weighs about 5.0 gm. at birth and 25 to 28 gm. in maturity. Its growth in early infancy is a little slower than that of the brain as a whole but the total relative increase after birth is somewhat greater.

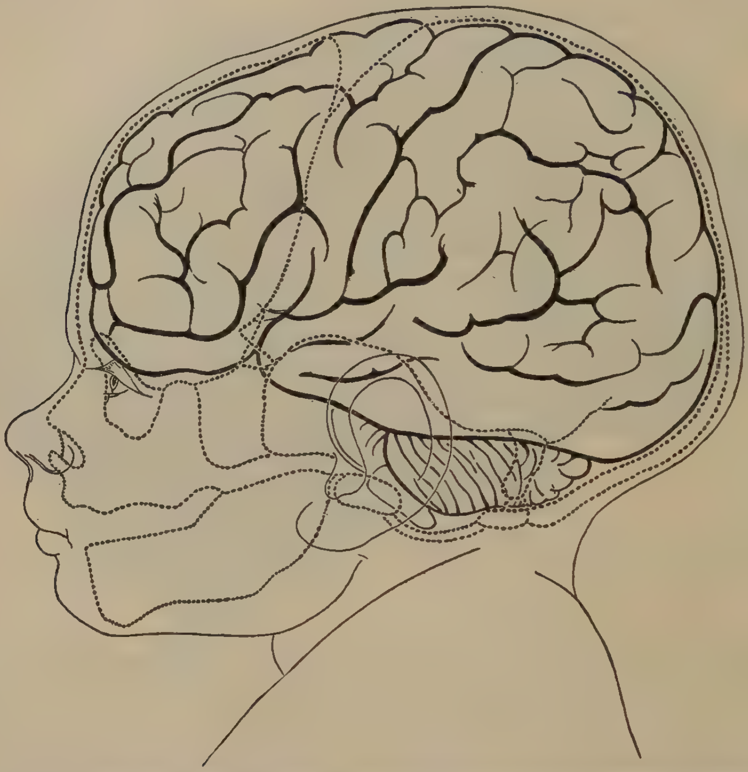

FIG. 181.—Lateral view of the head of a newborn child showing the topography of the skull and brain. Surface outlines in light line, skeletal structures in broken line, brain in heavy solid line. (After Merkel, Handb. top. Anat.)

The state of development of the sulci of the cerebrum at birth is illustrated by Fig. 180, a left lateral view of the brain of a full-term fetus. As will be seen from this figure, the general arrangement and condition of the sulci does not differ greatly from that of the adult. New lateral branches of established sulci may appear and the fusion of isolated segments to form continuous furrows may take place after birth, but these changes are small and are accomplished in the first month or so of post-natal life. The insula, or island of Reil, is not as completely covered at birth as in later life.

Space will not permit the discussion of the finer structure of the brain in this summary. The reader is recommended to the work of

Brodmann,[338] Flechsig,[342] and Hammerberg[344] for information on this subject.

The topographic relations of the more important sulci to the skull are somewhat different in the child and in the adult. The post-natal changes in these relations are brought about not as much by the shifting of the sulci, although this process has been described, as by developmental changes in the calvarium. In the infant the lateral fissure (of Sylvius) is more oblique than in later life, and lies from 1.1 to 1.5 cm. above the squamosal suture. It extends backward and upward nearly to the parietal eminence. The lateral fissure and the squamosal suture approach one another during childhood, but the time at which the adult relationship is acquired is probably very variable; Symington[14] sets it at the eighth or ninth year. The central sulcus (fissure of Rolando) lies entirely under the cover of the parietal bone in the infant as in the adult, but it is placed a little farther forward in the former. At birth and for a short time thereafter, at least, the sulcus is more oblique than in the adult. Fouillehouze[343] found the upper end to be from 30 to 35 mm. posterior to the bregma in the first few months of life, while the lower end may touch the coronal suture. After the third

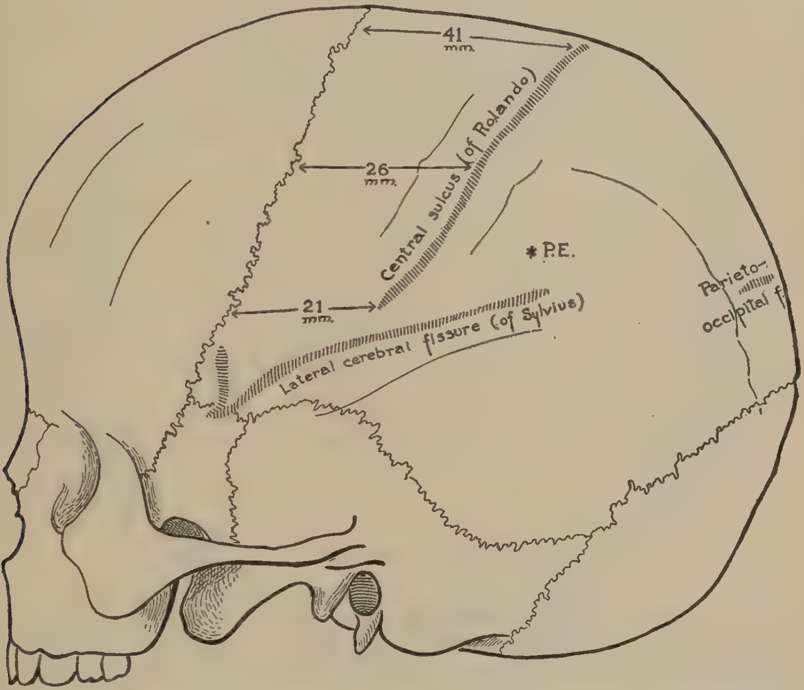
41 mm.
26 mm.
21 mm.
Central sulcus (of Rolando)
Lateral cerebral fissure (of Sylvius)
P.E.
Parieto-occipital f.

Fig. 182.—Lateral view of the skull of a child four years of age showing the position of the main cerebral fissures. P.E., parietal eminence. (After Davis from Fouillehouze.[343])

year the relations are the same as in the adult. The parietooccipital fissure in infants lies from 5 to 15 or even 20 mm. in front of the lamboid suture. This is relatively a little anterior to its position in the adult. Figures 181 and 182 show the position of the main fissures in early childhood.

The Meninges and Cranial Sinuses (Figs. 90–186)

The form and relations of the meninges in the child are very similar to those of the adult. The dura is more closely applied to the cranial bones in early life and its outer layer contains numerous osteoblasts. It is continued across the sutures and forms the inner layer of the fontanicular membranes. Judging from the data of Pfeister,[350] the dura grows at approximately the same rate as the brain and not at the general body rate; for its weight in the first month is about 22 gm. and this is only tripled by seven years.

The relation between brain volume and cranial capacity differs in the adult and child. In the newborn the brain occupies 97.5 per cent. of the cranial cavity and this relation is hardly changed in the first six years. After six years the space between the brain and the cranial wall steadily increases and in the adult the brain occupies, on the average, only 92.5 per cent. of the cranial cavity. In other words, the brain is much more closely applied to the wall of the skull during its period of rapid growth than in later life.

The topography of the cranial sinuses in the child has not been studied in detail.

The Spinal Cord (Fig. 151)

The weight, in the newborn, of the spinal cord without its dural covering or the spinal nerve roots is between 3 and 3.5 gm., being about one-eighth that of the adult. According to Pfeister the weight of the cord is doubled in the first five months, trebled in the first year, and quadrupled by the beginning of the third year. The spinal cord forms about 1 per cent. of the body weight at birth and about 0.25 per cent. in the adult. The weight of the spinal cord is to the weight of the brain at birth as 1:110, and in the adult (Pfeister) as 1:50.

At birth the spinal cord is from 15 to 17 cm. in length; a little more than one-third as long as in the adult. It doubles its length in the first 10 years of life. The length of the various segments of the cord are so variable at all times of life that no general statement can be hazarded as to their rates of growth, although it is said that the thoracic segment lengthens more, proportionately, than the others. The cord at birth commonly terminates at the lower border of the body of the second or the upper margin of the third lumbar vertebra, about one vertebra below the usual point of termination in the adult.

THE EYE (Fig. 183)

The post-natal growth of the eyeball corresponds very closely to that of the brain. At birth its average weight is from 2.5 to 3.0 gm. This is increased approximately two times in the first seven or eight years of life. In all, the weight of the eye-ball increases about three times between birth and maturity. During the same period the brain increases from three and one-half to four times and the body over 20 times.

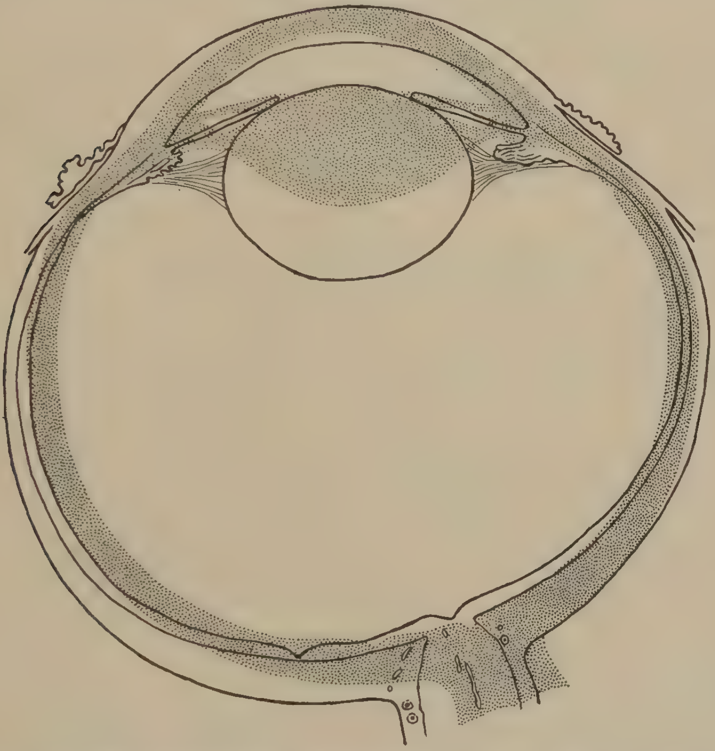

FIG. 183.—Semidiagrammatic representation of the eye of the newborn in median section superimposed upon a similar section of the eye of the adult. The structures are drawn at equal size. The newborn eye is represented in solid line, the adult in stipple. The newborn eye is magnified five times. (After Merkel and Orr.[360])

The volume of the eye increases slightly more but at the same relative rate as the weight.

Considerable difference in the averages of the several diameters of the eye-ball at birth is found by different observers. This is no doubt partly due to natural variation and partly to the deformation of the eye-ball after removal from the body. Weiss[365] in a series of 20 newborn children found the sagittal diameter to be 16.4 mm., the horizontal 16.0 mm., and the vertical 15.4 mm. In the adult the similar measurements are 23.85, 24.43, and 23.7 mm. Thus the sagittal diameter, according to these figures, is relatively a little greater in the newborn than in the adult. The actual increase in the lengths of the several diameters between birth and maturity is something less than one and one-half times for the sagittal diameter and a little more than one and one-half times for the vertical diameters.

The growth of the eyeball as a whole takes place in different regions in different periods of post-natal life. The divergence of the eyeball from a perfect sphere is more marked in infancy than in later life. This is due particularly to the great size of the posterio-temporal segment. In early childhood the anterior segment grows the most rapidly; in later childhood growth appears to be more localized in the nasal segment. After puberty the posterior segment completes its growth. This does not apply to the area of the posterior segment about the fovea centralis and the papilla of the optic nerve, for the distance between these two structures is as great in the newborn as it is in the adult.

The cornea in the newborn is relatively larger than in later life, being almost four-fifths the actual size of that of the adult. Its curvature is less pronounced than that of the adult.

The shape of the lens in the newborn and young infant is not markedly different from that found in later life. The familiar statement that the lens is much thicker relatively in the newborn than the adult rests upon observations made on fixed material and upon specimens which have been freed of their attachments. Both von Pflugk[361] and von Hipple,[357] who studied fresh lenses in section, found the thickness to be from 3.5 to 4 mm. and the equatorial diameter from 6 to 7 mm. Most earlier observers found the thickness of the lens to be more than two-thirds of its equatorial diameter. The equatorial diameter of the lens increases during the entire period of life up to an advanced age. In the period from birth to the end of the third decade it increases between a third and a fourth. The growth in thickness is not so regular for there seems to be a period of actual decrease in thickness in early childhood. This is probably due to the effect of the tension of the supporting structures on the plastic lens substance. After early childhood the thickness of the lens increases throughout the remainder of life.

During the growth of the eyeball its extrinsic muscles are slightly shifted from their original position. The reader is referred to the work of Weiss[365] on this subject for details.

The optic nerve increases more than one-half in diameter during the first year and by the end of that time is substantially the same size as in the adult. Most of this early increase is due to the myelination of the optic nerve fibers, a process which takes place mainly during the first three weeks of post-natal life. As in the adult, the optic nerve is slightly sinuous in its course through the orbit.

The lachrymal gland weighs at birth approximately one-third of its adult weight. At this time the parenchyma consists of narrow thick-walled tubes separated by a large amount of cellular connective tissue. The fat which is abundant in the adult gland is lacking in that of the infant. Although incompletely developed at the time of birth the gland has a limited power of secretion.

THE EAR (INCLUDING THE TEMPORAL BONE)

The ear can be treated only in the briefest manner in the present outline. Those desiring more detailed accounts are referred particularly to the papers of Alexander,[367] Brown,[369] Freligh,[371] and Symington.[376] The atlas of Müller gives excellent figures of the topography of the temporal region in childhood.

The Temporal Bone (Figs. 182, 184, 185).—At birth the temporal bone as a whole is approximately one-fourth the size of the adult. It consists of three divisions: The pars petrosa, the pars squamosa, and the pars tympanica, which are generally still separated by definite sutures. The styloid process is still entirely cartilaginous except for a small osseous granule near its upper end.

The petrous portion is relatively larger than in later life. It is directed more anteriorly and inferiorly and less medially than in the adult. The mastoid process is absent and the external surface of the bone presents a smooth flat area which is not elevated above the general surface of the skull in this region. The stylomastoid foramen, which is relatively larger than in later life, is found at the anterior edge of this area.

The pars squamosa is thin and smooth. The mandibular, or glenoid fossa, is of considerable size although very shallow. A true articular tubercle is lacking but the postglenoid process is well marked.

The pars tympanica or tympanic annulus has the form of a thin bony ring which is incomplete above. The upper extremities of the ring are usually fused with the inferior margin of the pars squamosa at the time of birth.

In the newborn the petrous and the squamosal portions of the temporal bone are almost always partially separated by a fissure, the petrosquamosal suture. This cleft arises behind the middle of the posterior limb of the tympanic ring, and extends upward and backward on the lateral surface of the bone to its superior margin. It then turns forward and runs in the roof of the tympanum until it reaches the anterior margin of the squamous portion of the bone. The petrosquamosal suture opens directly into the tympanic antrum in the newborn and in young children, and its presence accounts for the frequent spreading of middle ear infections to the meninges and for the formation of subperiosteal abscesses in early life.

The form of the temporal bone changes rapidly in childhood. The mastoid process generally appears as a small nipple-like projection during the latter part of the first year, but it does not extend below the general inferior margin for two or three years thereafter. The upper osseous center in the upper part of the styloid process fuses with the body of the bone soon after birth. A second lower center appears

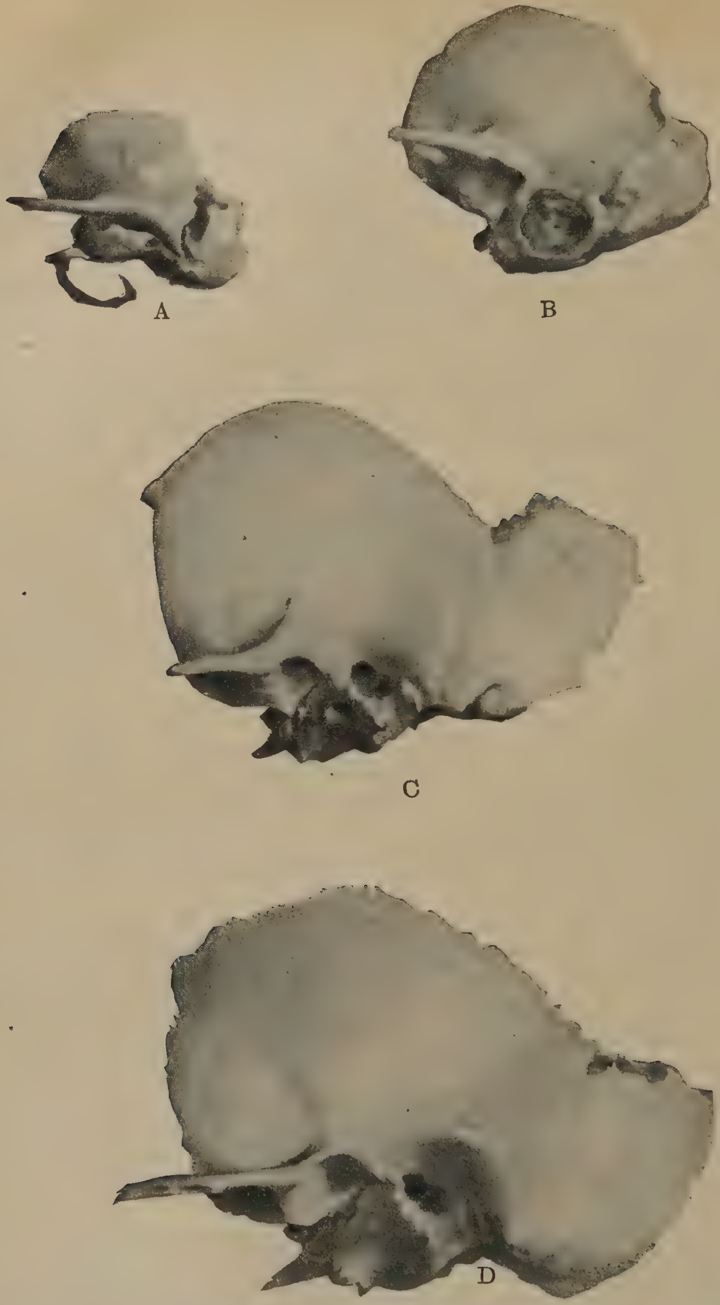

FIG. 184.—Four drawings of the temporal bone in early life. A, seven months fetus; B, full-term newborn; C, child three years old; D, child six years old. All natural size.

in the styloid cartilage about the eighth year, and joins the main bone about puberty.

The tympanic annulus is converted into a plate by the rapid growth of processes from its anterior and posterior sides. The lower part of the annulus does not grow as rapidly as do the sides and there is left a deep notch in the floor of the bony meatus. The processes from the sides of the annulus fuse inferiorly at about two years and the notch is thus converted into a foramen. This is generally obliterated in the next few years although in some cases it may persist in adult life. While the floor and sides of the bony meatus are formed mainly from the lateral growth of the tympanic ring, the roof is produced by the outgrowth of a bony shelf from the pars squamosa.

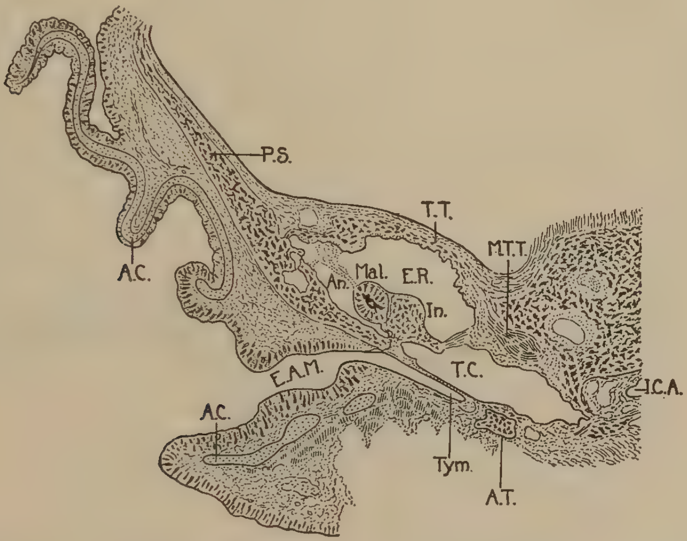

Fig. 185.—Vertical section of the ear of a newborn child. A.C., auricular cartilages; Ant., tympanic antrum; A.T., tympanic annulus; E.A.M., external auditory meatus; E.R., epitympanic recess; I.C.A., internal carotid artery; In., incus; Mal., malleus; M.T.T., tensor tympani muscle; P.S., squamous part of temporal bone; T.C., tympanic cavity; T.T., tegmen tympani; Tym., tympanic membrane. Four times natural size. (Slightly modified from Hammar.[374])

The closure of the petrosquamosal fissure is subject to the greatest variation in different individuals. Kisselbach[372] found it closed completely in about 4 per cent. of children in the first year, in from one-third to one-half of his cases between one and five years, and in 60 to 80 per cent. between 5 and 19 years. His statistics show no indication of a progressive closure of the fissure after the sixth year. In many cases it is obliterated except for minor holes and clefts.

The specimens illustrated in Fig. 184 show some of the more important gross changes in the form of the bone after birth.

The External Ear (Fig. 185).—The longitudinal dimensions of the external auditory meatus are subject to great individual variation, but in general they are about two-thirds those of the adult. The relative length of the tube is somewhat greater in early life than in maturity. In the infant the floor of the tube is formed externally of cartilage, and internally by a dense fibrous membrane which is replaced later by the bony outgrowth of the tympanic plate. The inner third of the roof is formed by the overhanging lateral surface of the pars squamosa while the outer two-thirds is cartilaginous.

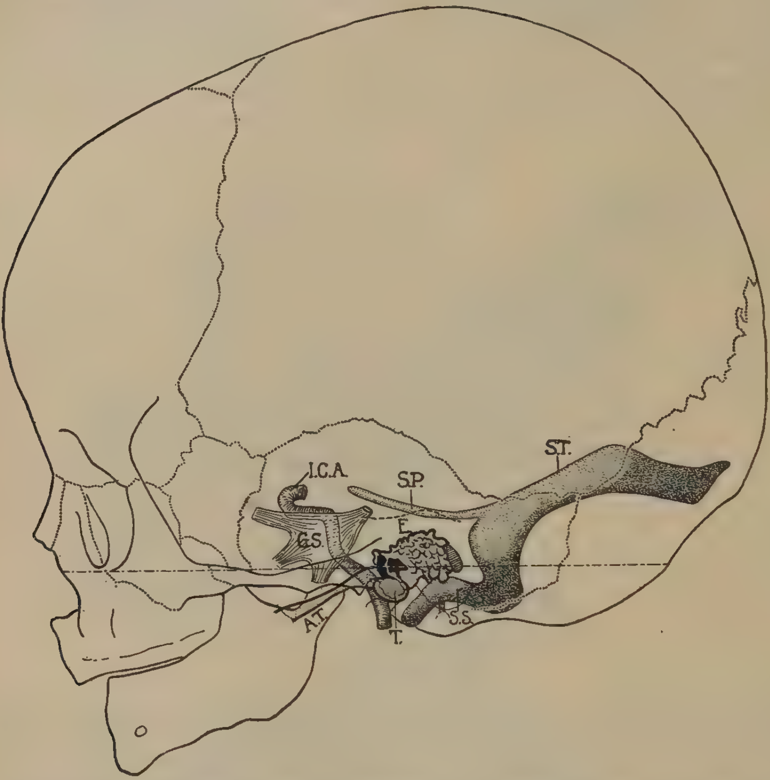

Fig. 186.—Left lateral view of the skull of a female child 12 months old, showing the topography of the ear. A.T., auditory tube; E., epitympanic recess, mastoid antrum, and mastoid air cells; G.S., semilunar ganglion; I.C.A., internal carotid artery; S.P., superior petrosal sinus; S.S., sigmoid sinus; S.T., transverse sinus; T., tympanic membrane. (After Müller.[375])

The lumen of the middle part of the tube is very narrow in infancy, but it widens out into a conical chamber near the tympanic membrane. At birth the lumen is filled by a mass of desquamated epithelial cells and vernix caseosa.

In infancy the course of the meatus is almost straight; it passes inward, downward, and slightly forward.

The Middle Ear (Figs. 185, 186, 187).—The cavity of the tympanum has practically reached its final size at birth. The average dimensions, as determined by Freligh from the measurement of 150 cases, are 9.5

mm. in its longest diameter by 7.5 mm. across. The promontory is well marked, as is also the prominence of the facial canal. The epitympanic recess (aditus ad antrum) and the tympanic (mastoid) antrum are quite as large if not absolutely larger in the infant than in the adult. In the late fetus the tympanic cavity is almost completely filled with a jelly-like tissue derived from the lining epithelium. This is generally replaced by fluid before birth and by air after respiration is fully established. Meconium and amniotic fluid have often been found in the tympanic cavities of newborn children.

The tympanic membrane has practically completed its growth by the time of birth. Its inclination is much the same in the infant and in the adult, the angle being generally between 50 and 60° in both. The external surface of the membrane is directed somewhat more anteriorly in childhood than in later life. The epithelia covering the inner and outer surfaces of the tympanic membrane are somewhat thicker in the child than in the adult, but the intervening connective tissue layer is about the same. The inner epithelial layer is ciliated at birth.

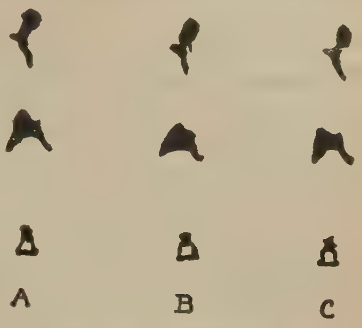

Fig. 187.—Drawings of the auditory ossicles: A, of a fetus of seven months; B, of a newborn child; C, of an adult. All natural size. (After Broman.[368])

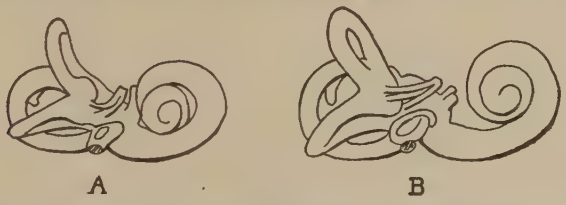

Fig. 188.—Casts of the labyrinth of the inner ear, three times natural size. A, newborn; B, adult. (After Alexander.[366])

The auditory ossicles reach their final size in the middle of fetal life. This is strikingly shown in Fig. 187.

The auditory, or Eustachian, tube is about 17 mm. long in the newborn or approximately half the length of the adult. According to the measurements of Symington, it grows rather slowly in the first year but rapidly thereafter, so that the adult length is approached by the end of the first period of childhood. The tympanic opening of the tube is quite as large in the newborn as in the adult, while the isthmus is absolutely as well as relatively wider. The pharyngeal opening, on the other hand, is relatively small. The bony part of the tube is relatively longer in infancy than in maturity. The course of the tube is almost horizontal in the infant, and the obliquity of the adult tube is acquired along with the increase in length of the nasopharynx in later childhood. The shifting of the pharyngeal ostium of the tube in childhood has already been described in connection with the nasopharynx. The "tonsil" of the tube is represented only by diffuse lymphoid tissue in the newborn. It acquires its final form in the third or fourth year.

The development of the mastoid cells is very irregular. Freligh[371] found them present in 30 per cent. of the large series of temporal bones of the newborn which he examined. In this series the largest cells were about 5 mm. in diameter. Most of these cells were located just posterior to the exit of the facial nerve, and none were found at the lower end of the mastoid portion of the pars petrosa. In childhood the core of the developing mastoid process is filled with fine cancellous bone, and as a rule this region is not invaded by the mastoid cells until nearly puberty. However there are cases in which the process contains cells of a considerable size at five or six years.

The Internal Ear (Fig. 188).—The structure of the internal ear in childhood needs no particular description. The bony labyrinth has attained almost its adult size and proportions at the time of birth. The careful series of measurements made by Alexander[366] show that most of the dimensions of the vestibule and semicircular canals increase about one-tenth during post-natal life while those of the cochlea, on the whole, increase rather less. Certain dimensions, such, for example, as those of the fenestra cochlea (fenestra rotunda), are practically the same in the newborn and the adult. Figures 188*a* and 188*b* are of casts of the osseous labyrinths of the newborn and adult drawn at natural size.

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CHAPTER IV

GROWTH AND DEVELOPMENT

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THE CHEMICAL FOUNDATION OF GROWTH

General Characteristics of the Growth-process

Regarded from the chemical point of view, the growth of animals consists, essentially, in the transformation of simple, unorganized food stuffs, such as inorganic salts, fats, carbohydrates, amino-acids, etc., into new chemical entities which, regarded collectively, form the organized protoplasm of the animal tissues. Growth, therefore, involves the synthesis of a variety of chemical compounds in due proportion and succession to one another.

This process obviously does not take place with uniform velocity throughout life. It is not at all unusual, for example, for an infant to grow at the rate of two pounds per month during the first months succeeding birth. Were this rate of growth maintained, we would weigh in the neighborhood of five hundred pounds at twenty years of age. Nevertheless, the process of growth is not one which undergoes a uniform retardation, diminishing in velocity by a uniform proportion per annum. On the contrary, the growth of children and of animals takes place in spurts separated more or less distinctly from one another by periods of relatively languid growth. Thus, the rate of growth *in utero* during the first half of gestation is so slow that prior to this period, the weight of the human fetus is inappreciable in comparison with that of the mother. This interval of slow growth is succeeded by the extraordinarily rapid accretion of tissue which characterizes development during the months immediately prior to and succeeding delivery.

Towards the end of the first year of extra-uterine life, however, there occurs a definite slackening of growth, which is not an artefact dependent upon weaning since it occurs just as strikingly in bottle-fed as in breast-fed infants. This resting period is succeeded by the relatively rapid growth of the third, fourth, and fifth years. Another pause or slackening of growth succeeds this to be followed by the energetic growth which accompanies adolescence.

The growth of man, therefore, consists of alternating periods of rapid and slow growth. If we plot the weight curve with weights as ordinates (vertical) and age in years as abscissæ (horizontal), we obtain a diagrammatic picture of the growth-process which is not a straight line, nor even a single curvilinear sweep like the outline of a parabola, or of the logarithmic curve which represents the progress of the ordinary type of chemical reaction. On the contrary, our diagram reveals distinct waves or large oscillations in the growth-process and resembles, as a matter of fact, the diagram which may be obtained by superimposing three S-shaped curves upon one another in such a manner that their adjacent extremities merge into one another. These waves or oscillations are not accidental; they occur at very nearly the same places in the growth curve of every normal child and, as such, are easily distinguishable from the relatively slight irregularities or fluctuations of growth which every individual child will display more or less frequently during its development. In the average growth-diagram constructed from the growth-data supplied by any large number of infants, these large oscillations or waves reveal themselves very distinctly, while the accidental and individual fluctuations will cancel out and disappear since as many of them are positive (*i.e.*, supernormal) as negative (*i.e.*, subnormal). The large fluctuations, however, having a definite physiological significance, remain unaffected in magnitude and position. In fact, the greater the number of children we investigate, the more definitely do they appear in the diagram.

These large oscillations or waves of growth I have termed "growth-cycles." [112, 116, 120] In the growth of man there are, as I have said, three such cycles superimposed upon one another. Each cycle begins with a period of relatively slow growth followed by a period of very rapid growth and terminates in another period of slackening growth. In the case of the first two cycles, this slackening of growth is followed by the fresh spurt or acceleration due to the suceeding cycle. In the case of the third or adolescent cycle of growth, the period of slackened growth-velocity insensibly merges into the period of relatively stationary development which we recognize as the adult condition. This developmental stasis, however, may be interrupted, either by the repair incident to the replacement of tissue which has been injured or destroyed, or in the absence of such regenerative processes, by a vigorous and abnormal growth of malignant tumors. This last I am inclined to interpret as constituting the superposition of a fourth, and physiologically abnormal cycle of growth upon the third and normally final cycle in the development of man.[115]

Not only the growth of man but also the growth of every mammal which as yet has been carefully investigated consists of three complete cycles.[34, 42, 89, 100, 112] The growth of the guinea-pig at first appeared but to consist of only two cycles distinguishable with difficulty, the investigations of Read[110] have shown that in this mammal, the first growth-cycle is actually completed *in utero*, instead of being interrupted midway by birth, as it is in human beings.

In the accompanying figure the growth diagrams of human British males and of male white mice are compared (Figs. 189, 190).[120] The human growth-curve is constructed in part (first year) from my own observations upon the growth of British infants[126] and in part (fourth to twenty-fourth years) from the data collected by the British Anthropometric committee.[3] The resemblance between the two curves, allowing for the difference in the time-units employed, is of a very striking character.*

These growth-cycles, so definitely situated in the curve of growth, and so invariable in their occurrence that they may be clearly recognized in the growth of mice no less than in the growth of man, must have some very definite physiological significance. Since growth is essentially a chemical process resulting in the synthesis of living tissue from inanimate materials, these growth-cycles must have a chemical no less than a physiological significance. Each growth-cycle is approximately symmetrical about its center, that is, on either side of the point

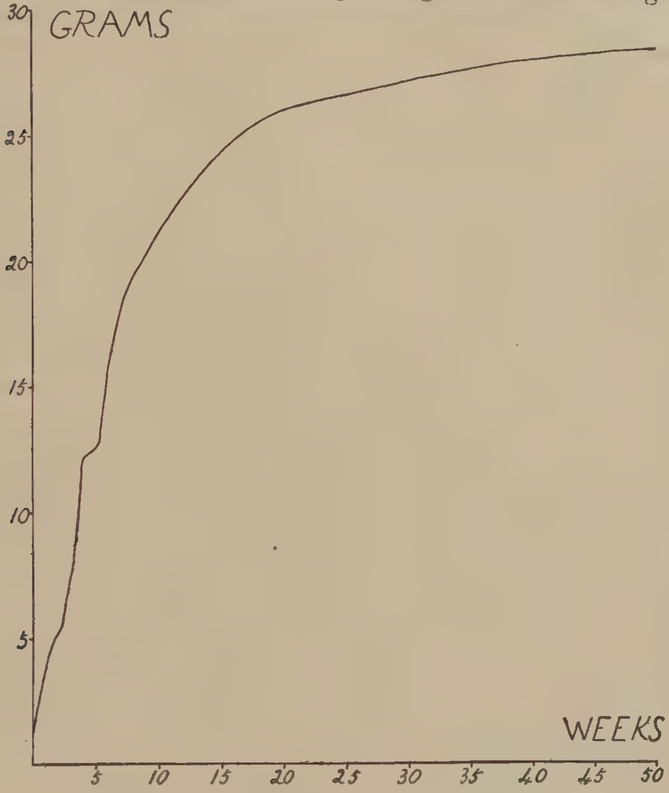

FIG. 189.—Growth-curve of male white mice.

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* A comparison of these two curves at once shows that the most notable characteristic in which the growth of man differs from that of mice consists in the relatively striking retardation of the third growth-cycle in man. As Friedenthal has pointed out[43] the magnitude of the "cephalization-factor" or ratio of brain-weight to body-weight is much higher in man than in other animals. Having regard to the high content of cholesterol in the tissues of the nervous system, and to the fact that an excess of cholesterol, administered to mice, greatly retards the initial portions of the third growth-cycle[125] it appears not improbable that the relatively low velocity and delayed onset of the third cycle in man may be in part a consequence of the cholesterol-retention incident to the building up of our relatively very large proportion of nervous tissues.

of most rapid growth. Considering each growth-cycle by itself, we have then, a chemical process which begins with relative slowness, increases progressively in velocity until it is about half completed, and then gradually diminishes to its termination. The inquiry now immediately presents itself whether any chemical processes of this general character are known to occur elsewhere than in the tissues of a growing animal.

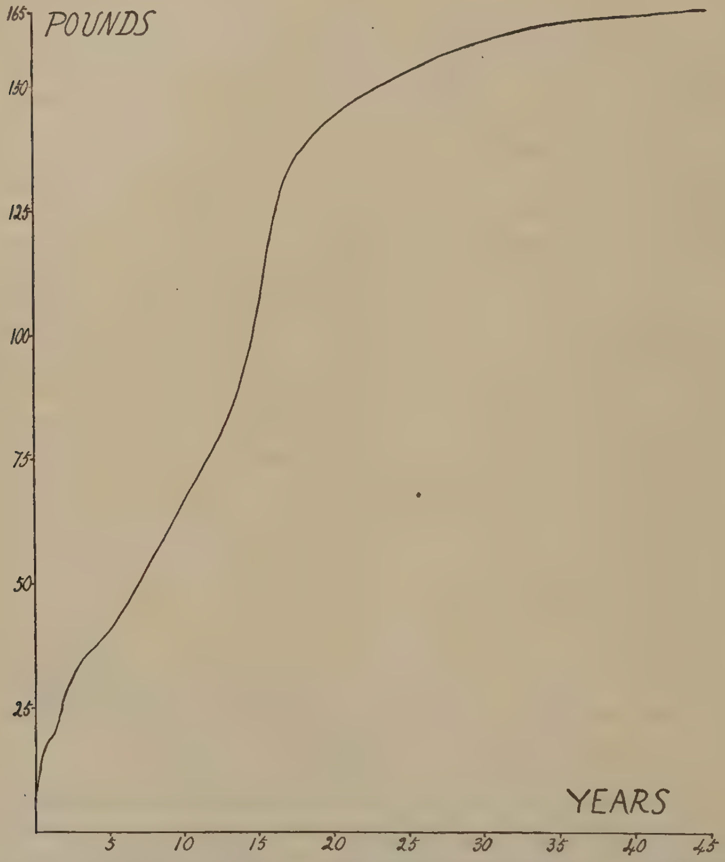

FIG. 190.—Growth-curve of human males (British Anthropometric committee).

As a matter of fact a number of processes of this character are known to the chemist. As examples, we may cite the decomposition of cane-sugar by boiling (neutral) water,[67] the decomposition of castor-oil in the pulverized seeds of the castor-oil bean,[26] the decomposition of methyl acetate by (neutral) water,[98] the oxidation or "tarnishing" of most metals, and the oxidation of a variety of organic materials.[85] All of these diverse processes have this feature in common, namely, that one of the products of the chemical change which is going on, has the property of accelerating, or "catalyzing" the further progress of the change. Thus, in the hydrolysis of cane-sugar by neutral water, a certain proportion of mucic acid is formed which accelerates the conversion of cane-sugar into invert-sugar. In the decomposition of methyl acetate, acetic acid, itself one of the products of the decomposition, accelerates the hydrolysis of the methylacetate. In the oxidation of the metals, the peroxides which are formed act as "carriers" of oxygen to the yet unoxidized portions of the metal. All of these processes are, in a word, "autocatalyzed" or self-accelerated. The fact that the reaction has already occurred is, up to a certain point, a favoring condition for its further occurrence.

The fact that each growth-cycle begins slowly and progressively increases in velocity until the moment of maximal growth velocity is attained at the center of the cycle, is sufficient in itself to show that the process of growth is autocatalyzed.[69, 70, 100, 112, 113, 114] Up to the moment of maximal growth-velocity, the preceding growth affords a condition or series of conditions favoring its continuance. It remains to inquire somewhat more specifically what may be the nature of the factor or factors which induce the initial acceleration of growth and of those which subsequently, in the latter half of the cycle, induce retardation of the growth-process.

In the instances of autocatalyzed chemical reactions cited above, the accelerating factor is a substance produced by the reaction, which specifically "catalyzes" or accelerates the reaction. The inhibiting factor which ultimately terminates the reaction by bringing it to a standstill is either the exhaustion of the material which is being transformed, as, for instance, the cane-sugar which is being hydrolyzed, or else the accumulation of the products of the reaction, for instance acetic acid and methyl alcohol in the hydrolysis of methyl acetate. In accordance with the law of mass action, acetic acid and methyl alcohol impede the hydrolysis of methyl acetate by enhancing the velocity of the reverse reaction in direct proportion to their concentration. Since the growth diagram so closely resembles the phases of these chemical reactions it may be fair to assume that catalyzers of growth are produced in the first or *autokinetic* phase during which the velocity of growth is progressively increasing, and that impeding factors are produced in the second or *autostatic* phase, which are attributable either to the exhaustion of an essential constituent of the reaction or to the accumulation of growth-products.

The problem becomes somewhat clearer when we consider the simpler case of bacteria growing in a limited amount of a given culture-medium. In this case, as McKendrick has shown,[82] phenomena are exhibited which are precisely analogous to those which characterize the growth of higher organisms. The growth of the bacterial culture measured by the total mass or number of bacteria produced at given time-intervals is at first extremely slow; it increases in velocity, however, at first almost in proportion to the number of bacteria produced. At a later stage, when the density of the population of the culture-medium has attained a certain maxium, growth is impeded and finally comes to a standstill.

These phenomena are interpreted by McKendrick in the following manner: under constant nutritive conditions, each bacterium is capable of giving rise to a certain number of daughter-cells in a certain interval of time. This potentiality is transmitted to its offspring, so that if the nutritive constituents of the culture-medium were inexhaustible, the velocity of reproduction would always be proportionate to the number of bacteria previously produced; in other words, while the time increased in arithmetical proportion the density of the bacterial population would increase in geometrical proportion. In practice, however, the ability of the culture-medium to supply nutritive materials to the bacteria is limited. Consequently, the rate of multiplication is reduced. McKendrick infers, therefore, that the rate of multiplication is proportional to two factors: 1, to the number of bacteria previously produced, and 2, to the concentration of the still available food-stuffs. This leads to the equation

$$\frac{dx}{dt} = kx(A - x) \tag{1}$$

where x is the number of bacteria per c.c., $A - x$ is the concentration of available food-stuffs and k is a constant proportionality-factor. The quantity of food material consumed is assumed to be proportional to the number of bacteria produced. Integration of this differential equation leads to the relationship

$$\log \frac{x}{A-x} = K(t - t_1) \tag{2}$$

where x is the number of bacteria per c.c., at time t, A is the maximal density of population which is attainable in a given culture-medium, $K(= kA)$ is a constant proportionality-factor, and t_1 is the time at which the density of the bacterial population has attained half its maximum.*

The relationship between the number or mass of bacteria produced and the time of incubation which is expressed in equations 1 and 2 is, however, identical with that which expresses the relationship between weight and age in any given growth-cycle of an animal or plant. [112, 113, 114] It is also identical with the relationship between the mass of the products and the time in autocatalyzed chemical reactions such as the hydrolysis of methyl acetate.[85, 98, 99] The question, therefore, presents itself, *viz.*, whether the process of growth in a multicellular organism such as a mammal is comparable to an autocatalyzed chemical reaction, or whether McKendrick's interpretation of the growth-curve of a bacterial population does not offer an alternative explanation of the facts. In other words, two alternative possibilities would appear to exist: the one, that the accelerative factor in growth is a chemical substance, as it is in autocatalyzed chemical reactions; the other, that it is simply due to the multiplication of cells each of which is possessed of like potentialities of reproduction.

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* I have slightly, but unessentially, modified McKendrick's formulation of this relationship in order to make clearer the analogies which will subsequently be drawn.

On closer analysis it will be seen, however, that these interpretations, at first sight alternative, are in reality identical. Reverting to the case afforded by the multiplication of bacteria in a limited amount of culture-medium, and looking to the beginning and end of the process, we see that the increase in bacterial population means, essentially, that the simple unorganized constituents of the culture-medium have been transformed into the substances composing the bacteria. Any acceleration experienced by the process must ultimately be due to the preceding synthesis, irrespective of the fact that the synthesis takes place in a heterogeneous system, *i.e.* in the separate particulate masses which form the individual bacteria. When we say that each bacterium has a like potentiality of reproduction, we clearly express the fact that the synthesis of bacterial cell-substances which results in the production of a cell is a favoring condition for the production of new cells. In other words the substances comprising the bacterium accelerate the production of new masses of bacterial substances. In ultimate terms, therefore, the two interpretations of the phenomenon are identical. The only essential difference between the more familiar cases of autocatalysis, such as the hydrolysis of methyl acetate, and the process of cell-multiplication is the fact that in the latter process the reaction takes place in a heterogeneous chemical system, *i.e.*, within the particulate masses comprising the cells. Instances of autocatalysis in heterogeneous systems are, however, abundant in chemical literature, the oxidation of metals in contact with air being a familiar illustration of autocatalyzed reactions of this type.

The accelerative factor in the process of growth is, therefore, either a chemical substance or substances, or a chemical condition which is strictly analogous to the accelerative factor in less complex autocatalyzed reactions. In fact the autocatalytic character of the growth-process follows of necessity, from the fundamental characteristic which, more than any other, distinguishes living from non-living material, namely its potentiality of unlimited reproduction. When we assert that living cells all possess like potentiality of reproduction, we merely state in morphological terminology that the production of living matter is a self-sustained or autocatalyzed phenomenon. Just as the production of living from inanimate matter is essentially a chemical process, so the acceleration of production which is consequent upon the multiplication of the particulate resultants of the process is, viewed from the chemical standpoint, evidence that substances are produced in the creation of living matter which have the essential property of catalyzing its further manufacture. We shall have something to say in other portions of this chapter regarding the possible nature of these substances.

It remains to consider what may be the probable nature of the *inhibitive* factor which ultimately brings the process to a standstill and which predominates over the accelerative factor during the latter half of each growth-cycle. In the simpler instances of autocatalysis, as we have seen, the inhibitive factor may be either the exhaustion of the material undergoing transformation, or, the accumulation and consequent "back pressure" of the products of the reaction; or on the other hand, it may be that both of these factors play a part in determining the magnitude of the inhibition. Either of these alternatives would yield the time-relations expressed in the Equations 1 and 2, for the following reasons:

In case the velocity of the reverse reaction is, at all stages of the transformation, negligible in comparison with that of the forward reaction, then the only inhibitive factor must be the exhaustion of the material undergoing transformation. The velocity of the process will be, as usual in chemical reactions, proportional to the mass of untransformed material and also to the mass of catalyzer, that is, in these instances, to the mass of the products of the reaction. Calling the mass of the products of the reaction at any moment x, and A the initial amount of the material undergoing transformation, we have the relation:

$$\text{Velocity of transformation} = \frac{dx}{dt} = \mathrm{k}x\ (a - x) \qquad (3)$$

which is identical with equation 1.

Coming, now, to the case in which the velocity of the reverse reaction is so considerable as to be comparable with that of the forward reaction, we will assume, in the first instance, that the materials undergoing transformation (or foodstuffs in growth) are inexhaustible, *i.e.* are constantly being renewed so that the mass of material undergoing transformation is a constant which we may denote by the symbol a. The velocity of the forward reaction will then be, as in the above instance, proportionate to the mass of the catalyzer (= products of the reaction = x) and also to the constant mass of material undergoing transformation, that is, to a. The velocity of the reverse reaction (formation of the products of the reaction into the initial substances again) will be proportionate to the mass of the products (= x) but also to the mass of the catalyzer (= x), because in the majority of instances of "typical" catalyzes, the catalyzer accelerates both the forward and the reverse reactions in equal proportion.[85, 99] The velocity of the reverse reaction at any moment will therefore be proportionate to x^2, and the net velocity of the process, being the difference between the velocities of the forward and the reverse reactions, will be given by

$$\frac{dx}{dt} = k_1ax - k_2x^2 \qquad (4)$$

in which k_1 and k_2 are the velocity proportionality-factors of the forward and reverse reactions respectively. Rearranging the terms of the equation, this may be written

$$\frac{dx}{dt} = k_2x\left(\frac{k_1}{k_2}a - x\right) \tag{5}$$

which is again identical with equation 1, with the exception that the constant A, denoting the maximal attainable value of x, is now not the initial mass of material undergoing transformation, but the initial mass multiplied by the constant ratio of the velocity-constants of the forward and reverse reactions.

The third possibility is that afforded by the case in which both the exhaustion of the material undergoing transformation and the accumulation of the products, contribute to the inhibition and ultimate stoppage of the process. In this case the velocity of the forward reaction will be proportionate to $x(a - x)$ while that of the reverse reaction will be, as in the above instance, proportionate to x^2. The net velocity of the process will therefore be

$$\frac{dx}{dt} = k_1x(a - x) - k_2x^2 \tag{6}$$

which may be written

$$\frac{dx}{dt} = (k_1 + k_2)\,x\left(\frac{k_1}{k_1 + k_2}\,a - x\right) \tag{7}$$

which, again, is identical in form with equation 1.

In the case of the growth of bacteria in a limited quantity of culture-medium, McKendrick assumes that the inhibitive factor is simply the exhaustion of available foodstuffs, *i.e.*, that it corresponds to the first of the three alternative possibilities outlined above.

In the growth of the higher animals it is difficult to see how limited availability of foodstuffs could be a deciding factor in the inhibition of normal growth. The foodstuffs are constantly renewed and circulate in the fluid media, bathing the tissues of the body, not only in sufficient proportion to maintain the equilibrium previously attained, but even in adult animals in considerable excess of this necessary minimum. The destruction of the excess constitutes the "exogenous" as contrasted with "endogenous" metabolism. Moreover, if a portion of the tissues of an adult animal be injured or destroyed, the process of growth immediately recommences and is expressed in the phenomenon of regeneration; in other words, removal of the products of growth immediately re-initiates the growth-process, just as removal of the products of a "balanced" chemical reaction at equilibrium immediately re-initiates the forward reaction. We must infer, therefore, that in the growth of mammals it is the accumulation of the products of growth, which inhibits the process and not the exhaustion of nutritive materials.

In the analogous case afforded by the multiplication of infusoria in hay infusions, it has been shown that when two infusoria are isolated into the same drop of culture medium, the rate of production of new cells is not twice, but from four to sixteen times as rapid as it is when a single individual is isolated into a drop of the same size.[131] This mutually accelerative effect is not due to conjugation, for under the conditions of the experiment conjugation does not occur, and if it did occur the effect would be to cause retardation rather than acceleration of the reproductive rate. Evidently some substance is discharged by the infusoria into the medium which they inhabit which accelerates their reproductive rate. The presence of such an accelerative substance in a fluid which has been populated by multiplying infusoria may be directly demonstrated by the acceleration of reproductive rate which ensues when such fluid, filtered free from infusoria and boiled, is added to the fresh nutrient medium into which other infusoria are isolated. The "bios" phenomenon of Wildiers [33, 39, 60, 157] probably indicates that similar substances are produced by all living cells. Hence the autocatalyst of growth must be conceived not only as residing within the cells themselves, as implied in McKendrick's theory of bacterial multiplication, but also in the medium which the cells inhabit. There is much evidence to show that the accelerative substance is elaborated in the nucleus and is partly discharged into the surrounding medium at the moment of nuclear division, when the nuclear membrane has dissolved. On the other hand the retardation or suppression of multiplication which occurs in a fully-populated infusorial culture is not due to exhaustion of the available foodstuffs, because the filtered culture medium still permits vigorous reproduction of infusoria isolated into it from young cultures. Nevertheless, infusoria from old cultures develop much more slowly in old culture fluid than in fresh hay infusion, and the maximal resultant population is very scanty. Evidently the failure of the old cultures to maintain unlimited reproduction is due to an unsuitability of the old culture medium for the reproduction of the cells which inhabit it. This unsuitability is believed to be due to the accumulation of the nuclear autocatalyst both within and without the cells, accelerating the reverse reaction of nuclear synthesis to the point of equality with the velocity of the forward reaction, so that further synthesis of nuclear material, and consequently further production of new cells is inhibited. Mere dilution of the old culture fluid permits relatively rapid multiplication of individuals originally isolated from it and subsequently restored to it.

We infer, therefore, that the process of growth is determined by a series (in mammals usually three) of autocatalyzed chemical reactions in which the factor which determines the retardation and ultimate equilibrium of the process is the accumulation of the products, *i.e.*, the growth itself.

Two apparent difficulties, however, confront this mode of interpreting the phenomena of growth. In the first place, the processes which underlie and accompany growth are clearly multiplex and not to be expressed as consisting of a single molecular transformation; consequently we are led to inquire how it is possible to represent the process by a formula expressing the time-relations in a simple autocatalyzed reaction in which the forward reaction involves the transformation of only a single species of molecule. In fact, we must infer, that the complex sum of processes which constitute growth all wait upon and are conditioned by some single transformation which is autocatalyzed. In any series of concatenated chemical reactions, the rate of production of all or of any one of the products is determined by the specifically slowest reaction[85] because this interposes a barrier between the initiation and the completion of the process; the final products of the series of reactions cannot appear any faster than the slowest reaction permits. The governing or "master" process in the sum of processes constituting growth must, therefore, be the specifically slowest essential chemical reaction.[130]

The second apparent difficulty is that which is occasioned by the fact that, morphologically considered, growth consists of two separate processes, namely cell-multiplication and the growth of the individual cells by intussusception. Under certain conditions, for instance in the initial stages of embryonic development, cell-multiplication is almost the exclusive evidence of development, while under other conditions, for instance, in normal adult multicellular animals, the latter form of growth, *i.e.*, growth by intussusception to replace tissue-waste, is the predominating type. Is it possible, one may inquire, to regard two such morphologically distinct processes as parts of one and the same chemical process?

The difficulty is apparent, and not real, for growth by multiplication is always preceded by and evidences growth by intussusception. The subdivision of the total mass of products formed into individual cells no more affects the essential character of the antecedent processes than the subdivision of calcium sulphate into particulate crystals affects the progress or the final equilibrium in the interaction of sulphuric acid and calcium hydrate. While the reaction is proceeding, new crystals are constantly being formed. When the reaction has attained equilibrium, calcium sulphate is redissolving and being reprecipitated at the surface of every crystal; yet the quantitative laws which govern the reaction are in no wise different at equilibrium from those which obtain while the reaction is still "unbalanced." The formation of a particulate crystal or of a new cell merely registers the attainment of a certain physical condition which is a necessary consequence of antecedent and concurrent chemical phenomena, which do not cease with and are not initiated by the physical subdivision of their product into parts.

The subdivision of living matter into cells is, in fact, no more than a device which ensures the relative constancy of the mass of nutriment available for the tissues. For if living matter were synthesized in one coherent mass, the nutrient material necessary for its repair, *i.e.*, to replace the loss due to the reverse reaction and maintain the balance of forward and reverse reaction which is characteristic of chemical equilibria, would soon be so far distant from the locality of tissue-degradation that the time consumed in their diffusion thereto would become comparable with or even greater than the time consumed in the breaking-down of an equivalent mass of living matter. Progressive autolysis of the interior of the mass would be a necessary consequence, and the living material would ultimately be confined to the periphery of a hollow shell. The various and elaborate circulatory mechanisms of the higher organisms are all means to the same end, and their absence, as in certain carcinomatous growths, leads to precisely the condition depicted above, namely, progressive autolysis of the interior of the mass. From this point of view the constancy of the ratio of surface to volume exhibited by the cells of any given species[25, 35, 142] and the relative invariability of this ratio in the various species of mammalia[40] are separate evidences of the essentiality of a fixed proportion of available nutrient materials for growth and the maintenance of the equilibria in which it culminates.

Summing up these prefatory remarks we may therefore state:

1. That the growth of man and of animals takes place in periods or cycles in which slow and rapid growth alternate, three of the cycles being usually appreciable in magnitude.
2. Each of these growth-cycles is the expression of an underlying self-accelerated chemical process.
3. The accelerating factor is some substance or group of substances produced during growth.
4. The supply of nutriment capable of transformation into living tissues may, in normal animals, be regarded as constant and undiminished by the process of growth itself.
5. The inhibitive factor which ultimately brings the growth in any given cycle to a standstill is the accumulation of the products of growth.
6. Removal of these products, as by local death or injury or by general inanition, reinaugurates the process of growth which continues until equilibrium is reattained.
7. The sum of the processes constituting growth are governed and determined in rate and magnitude by the specifically slowest essential process.
8. Cell-multiplication and cellular growth by intussusception are manifestations of one and the same underlying process, the former phenomenon being dependent upon the latter and occurring, as a rule, whenever the rate of growth by intussusception exceeds a certain critical limit.

The Substrates of Growth

The substrates of growth, *i.e.*, the material out of which living tissues are synthesized, are the foodstuffs, namely oxygen, water, inorganic salts, carbohydrates, fats, proteins and the various "accessory foodstuffs" or vitamins. In the period of biochemical research which immediately followed the fundamental investigations of Liebig and Voit, the application of the laws of the conservation of matter and energy to the phenomena of growth and metabolism appeared to supply all the necessary clues for the interpretation of the relationship of the foodstuffs to the maintenance of life. With the increasing refinement of our knowledge of the intimate chemical structure of the foodstuffs, themselves, it has become increasingly apparent to us during the past decades that it is not sufficient merely to supply an animal or a human being with a sufficiency of nitrogen, carbon, oxygen and calories to replace his daily waste, in order to maintain the equilibrium between waste and repair in his tissues, not is it even sufficient to supply these desiderata in digestible and assimilable form. Furthermore, it is necessary to supply irreducible minima of specified atomic groupings or complexes of nitrogen, carbon, hydrogen, oxygen, etc., which, it appears, are essential constituents of living matter and yet are not synthesizable by animal tissues. Thus, the pyrrole grouping, for example, which is an essential building-stone of hemoglobin, would appear to be as much an elementary requirement of animals as nitrogen or carbon itself, inasmuch as they are unable to synthesize it from other carbon and nitrogen complexes in the diet and, lacking it, are just as assuredly suffering starvation as if they were lacking one of the more elementary desiderata (1).

The variety of these essential constituents of the diet with which we are acquainted is already very great and is unquestionably destined to grow with increasing refinement and variety of investigation. It is highly probable that many of the raw materials from which the various internal secretions are synthesized are dietary constituents of this essential type. For example, the iminazolyl grouping, which in all probability forms an essential constituent of the active principles of the pituitary body,[2, 122] the catechol grouping, which is an essential component of the molecule of adrenalin,[7] and the indole radical, which from the observations of Kendall would appear to be a component of the active principle of the thyroid,[65] are examples which will serve to illustrate the essential importance of specific molecular groupings or arrangements of atoms, which, if not synthesizable by animal tissues, must necessarily form a part of the diet in order to maintain bodily equilibrium, and to a still greater extent, render normal growth a possibility.

The clearest indication of the dependence of tissue-synthesis upon the presence of specific atomic groupings in the dietary is, however, afforded by the investigations of Willcock and Hopkins[58] and of Osborne and Mendel[93, 53] who made a study of the adequacy of various pure proteins to supply the nitrogen-requirements of growth and maintenance.

The investigations of Emil Fischer and of many others during the past twenty years have shown us that the various protein constituents of tissues and of the diet are built up out of varying proportions of a limited number (nineteen in all) of amino-acid radicals which are linked together in long chains. Now certain of these nineteen radicals are lacking in some of the proteins. Consequently, the administration of such proteins to growing animals as the sole source of nitrogen in the diet, enables us to ascertain whether the amino-acid which is thus lacking is synthesizable by animal tissues, for it is not present in the diet and it must be synthesized if normal tissues are to be produced by the animal.

From the investigations cited, it appears to follow that the only amino-acid radical which is synthesizable by animal tissues is glycocoll, or amino-acetic acid. Of the remainder it is probable that all must be present preformed in the diet in order to permit the accretion of living tissue. At all events, this requirement has been positively established for several of the amino-acid radicals, for example, lysin, tryptophane, and tyrosin.

Zein, which is the alcohol-soluble protein of maize, is lacking in glycocoll, tryptophane, and lysin. Now the investigations of Willcocks and Hopkins and of Osborne and Mendel have shown that is zein be the sole source of nitrogen in the diet, not only the accretion of fresh tissue but also the maintenance of that already formed becomes impossible, so that, even though the animal be supplied with abundance of nitrogen, carbon, salts in correct proportion, water, and calories, it nevertheless dies of inanition. If tryptophane be added maintenance becomes possible, but not growth. On such a diet, even when supplied with gliadin, which lacks only glycocoll and lysin, a young animal lives but ceases to grow, maintaining always an infantile appearance. Readmission of the constituent absent in the diet [94] restores full capacity to grow until what would normally be a "ripe old age." Upon addition of lysin as well as tryptophane normal growth and maintenance are at once rendered possible, the glycocoll being synthesized by the animal itself. Evidently the endogenous metabolism or waste of lysin, incidental to and an essential consequence of life, is reducible to zero, possibly because a limited supply of lysin may be utilized over and over again in the processes of waste and repair. On the other hand, the endogenous metabolism of tryptophane is not reducible to zero. An inevitable waste occurs, and, the tissues of the animal being unable to synthesize it from other nitrogenous constituents of the diet, tissue waste exceeds tissue repair, with the ultimate and inevitable result of death due to loss of tissue.

It has long been known that gelatin is a "sparer of protein," *i.e.*, can furnish a portion but not the whole of the nitrogen in the diet. We now recognize that this is due to the absence of tyrosin and tryptophane from the molecule of this protein.

The proteins of seeds are generally deficient in one or more of the amino acids required for the synthesis of protoplasm. Nor do they supplement each other's deficiencies satisfactorily when they are mixed in the diet.[80, 93, 94, 95, 96, 97] In the case of Maize the deficiency of the protein leads, in human beings, to the development of Pellagra, when the nitrogen of the dietary is derived almost exclusively from this source. An analogous condition has been induced in the chimpanzee by restricting the protein in the diet to the Zein derived from maize, and when the condition had not persisted for too long a period it was found possible to check it and prevent a fatal outcome, by the administration of Tryptophabe.[22]

In addition to these molecular groupings of known constitution others, at present chemically undefined, are known to be necessary for the synthesis and maintenance of the tissues. These are the "accessory foodstuffs" or Vitamins.*

There are at present known to be three classes of accessory foodstuffs, namely a fat-soluble accessory, or Vitamin A; a water-soluble accessory or Vitamin B; and the anti-scorbutic accessory or Vitamin C. The fat-soluble accessory is contained in animal fats with, the exception of lard which is usually deficient in it. If, however, the pigs have been fed with a lavish supply of green food the lard derived from them may contain appreciable quantities of this accessory.[37, 49, 81, 164] It is lacking in the majority of vegetable oils and therefore, of course, in the hydrogenated vegetable oils which are now used extensively as substitutes for lard. It is exceptionally abundant in cod liver oil. It resists heating, but is destroyed by simultaneous heating and exposure to oxygen, as by aeration.

Absence of the fat-soluble accessory from the dietary results in failure of young animals to grow and a decline of the fertility of mature animals. Hence growth upon a fat-free diet cannot be maintained, no matter what excess of carbohydrate may be furnished.[28, 72, 77, 79, 87, 148] Moreover, animals fed upon a diet deficient in this accessory frequently develop Xerophthalmia (keratitis), arising from deficient resistance of the tissues of the cornea to bacterial invasion.[17, 147] It is suspected that deficiency of this accessory plays an important part in the etiology of rickets.[54, 74, 83]

The water-soluble vitamin is contained in the cuticle and germ of seeds and in aminal tissues. It is rapidly destroyed by autoclaving at a temperature considerably above the boiling point of water, and more slowly by boiling. Crystalline preparations of a high degree of potency have been prepared by Funk.[44, 45, 46, 47] Williams and Seidell,[160] and others, but purification of these preparations has always, so far, been attended by loss of potency, and the chemical relationships of the active substance have not yet been possible to define. Deficiency of this accessory is responsible, in human beings, for the disease of "beri-beri" prevalent in many parts of the East. In fowls or pigeons a diet of polished rice induces polyneuritis resulting in paralysis and finally in death. The condition is alleviated with extraordinary rapidity by the administration of aqueous extracts of the germ or husks of rice. The growth of young rats is totally inhibited by a diet lacking this accessory.[92]

The antiscorbutic accessory or Vitamin C is contained in the juices of acid fruits, the "Swede" turnip and the tomato. It is rapidly destroyed by heating and is therefore absent from thoroughly cooked food. Absence of this accessory leads to scurvy in human beings and in the guinea-pig, while in other animals, although symptoms recognizable as scurvy do not appear, growth is diminished or altogether checked.[8, 21, 23, 32, 48, 62]

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* It would be advisable to designate these chemically undefined dietary essentials "accessory foodstuffs," as originally proposed by their discoverer, Gowland Hopkins, reserving the term "Vitamin" for the particular substance, or group of substances, to which it was originally applied by Funk, namely the water-soluble accessory. Then in the future, when these substances become chemically defined, it will probably be found that the term "Vitamin" designates a group of closely related chemical substances, while the "accessory foodstuffs" may be of very diverse chemical constitutions. However, the present custom is to designate the three established accessories respectively, Vitamin A, B, and C.

From these investigations it is clear that the elementary substrates of growth are in all probability very numerous and represent a variety of chemical groupings superadded to the more elementary requirements of nitrogen, carbon, and calories.

It is furthermore evident that growth, like all other chemical transformations, is absolutely dependent upon its raw materials or substrates and cannot occur in their absence. On the other hand, the capacity to grow, as the above-cited investigations of Osborne and Mendel reveal,[94, 95] is not determined by age, but, as we concluded in the preceding section of this chapter, by a lack of balance between the forward and opposed reactions of tissue-synthesis and tissue-degradation, so that upon admission of the necessary substrates, no matter what the age prior to death of the animal may be, growth occurs and continues until equilibrium or equality of the velocities of tissue-synthesis and tissue-degradation, is attained. Thus we again reach the conclusion, this time from a totally different angle, that the relatively stationary weight of an adult animal is determined by the accumulation of the *products* of growth and not in any sense by the exhaustion of its *substrates.*

CATALYZERS OF GROWTH

We have all been rendered familiar, during the past two decades of scientific thought, with the conception of "catalyzers." The various digestive ferments will immediately be recalled to mind in this connection. The catalyzers are substances which, when added to a chemical reaction, greatly accelerate it without being necessarily consumed in the process. Thus, a small concentration of acid enormously accelerates the decomposition of cane-sugar or of starch by boiling water; yet the acid can be recovered unaltered in amount or composition from the mixture after the reaction has been completed, and may even be used over again to "invert" a fresh batch of cane-sugar. A minute quantity of pepsin or of trypsin will enormously accelerate the decomposition of protein by water. In fact, the quantity of protein so decomposed may amount to five hundred thousand times the weight of pepsin employed to catalyze the process.

If a catalyzer is of the "typical" variety and is not in any degree consumed during the reaction which it accelerates, then it necessarily follows that it cannot alter the final equilibrium of the reaction, for a shift in chemical equilibrium means, generally speaking, that heat is either produced or absorbed, and the equivalent in work or heat must be supplied by external agencies or from some other collateral chemical reaction. Since the catalyzer introduces no condition not implied in its presence, the energy-change involved in a shift of equilibrium would of necessity, be equated by a change in the energy-content of the catalyzer which could only be supplied by its chemical transformation, *i.e.* by consuming it. It therefore, follows, that since the equilibrium in any chemical system is determined by the equality of the velocity of the forward and opposed reactions, a catalyzer of this type must accelerate the forward and reverse reactions in precisely equal proportion.[85, 99] This is an assumption which we have already made in deriving the formula of autocatalysis in the cases in which equilibrium is wholly or partially determined by the accumulation of the products (Equations 4–7, Section 1). It furthermore follows, of course, *that a catalyzer cannot initiate a chemical reaction which is not already proceeding, however slowly, in its absence.*

We have seen that the chemical processes which underlie the growth of animals are of such a nature that they produce their own catalyzers. If this be so, we are then immediately impelled to the conclusion that catalyzers of growth exist, *i.e.* substances which, perhaps in minute proportion and certainly quite independently of their nutritive or substrate-value, may profoundly modify the growth of living tissues. The question now arises whether any evidence, other than this inferential kind, is obtainable of the veritable existence of such catalyzers of growth.

The profound significance of the various endocrine organs in the processes of growth immediately suggests itself as affording just the kind of evidence which we seek. We know from abundant clinical experience, that disorders of the thyroid, thymus, chromaffin system, pineal gland, and particularly of the anterior lobe of the pituitary body are reflected in a disturbed development of the various tissues of the body,[9, 29, 143, 155] and the action of the secretions of the corporea lutea in stimulating the production of decidua[71] is a striking example of the intensity and specificity of growth-stimulation which may be brought about by agencies of this type.

We can hardly suppose that these organs are in reality digestive organs, or that the effects observed are to be interpreted as the results of sub- or super-nutrition. The very nature of the effects themselves precludes such a supposition, for while inanition or over-feeding affects all tissues more or less in the same manner* the disorders of the endocrine organs referred to, lead to an extraordinary disproportion of development, one tissue or group of tissues displaying over-growth and yet another, perhaps, displaying equally marked deficiency of development.

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* This statement must be accepted in a qualitative rather than a quantitative sense. It is true that the tissue-wastage consequent upon inanition attacks certain organs first, sparing the most essential organs, the heart and the brain, until all other resources have been exhausted. On the other hand over-feeding encourages the deposition of reserve-materials, subcutaneous fats, and deposits of glycogen. However, the disproportion of the effects of inanition and over-feeding upon different tissues is always of the same type, affecting all organs alike in some degree, and is never so marked as the disproportionate development of the several tissues which is observed, for example, in acromegaly.

We have seen that in the simpler undifferentiated organisms, such as bacteria or infusoria, the function of growth catalysis is inherent in every cell and that, moreover, a portion of the accelerative agent escapes, at every nuclear division, into the medium which the cells inhabit. Even in the higher and more differentiated organisms the phenomena of regeneration and repair, and of tissue-growth *in vitro* combine to show that ability to produce the autocatalyst of nuclear synthesis is a universal property of living matter. The fact that all extracts of living tissue appear to exert some measure of accelerative effect upon the multiplication of isolated yeast cells[33, 39, 60, 157] confirms the view that the autocatalyst of growth is inseparable from life itself. A striking demonstration of this principle and of the analogy which these accelerative agents bear to the true catalyzers is furnished by the fact that two types of growth of yeast may be distinguished; a very slow growth without "bios," and very rapid multiplication in its presence.[60] In other words the yeast cells are themselves able in time to produce the catalyst and even in the presence of minimal amounts, the reactions involved in nuclear synthesis nevertheless occur at a very low velocity.

Little is known about these universal catalysts of growth, their very universality having concealed, until very recently, the fact of their existence. The substance in tissue—or yeast— extracts which stimulates the multiplication of yeast is thermostable, soluble in water, in acid alcohol, and in glacial acetic acid.[39] The accelerative substance which is produced by infusoria is similarly thermostable.

In the higher and more differentiated animals the above-cited effects arising out of the activities of endocrine organs, suggest that in certain instances the underlying auto-catalysis of the growth of all types of tissue may in the case of particular tissues be aided by the production of catalyzers by special-groups or organs situated elsewhere in the body. It would, indeed, be surprising if this were not the case, in view of the specialization and delegation of function which characterizes the higher planes of organic evolution. As in other instances of specialisation the delegated function is not lost. Just as digestive ferments may be found in all tissues and not merely in the cells composing the digestive organs, and as the function of motility is or may be displayed by almost all cells at some period of their existence, and not merely by the muscle-fiber cells, so the function of growth-catalysis remains inherent in every cell, although in occasional instances the catalysis of some special type of growth is partially delegated to a special organ. Among the active principles of those endocrine organs which are known to profoundly affect the growth of specific tissues, therefore, we may look to find substances which, while not necessarily related in any way to the universal nuclear autocatalyst, may nevertheless exert analogous effects upon the growth of these tissues.

Investigations upon both normal and pathological growth extending over a number of years, which have been conducted in my laboratory and elsewhere[6, 15, 18, 63, 66, 115, 120, 121, 122, 123, 132, 133, 134, 135, 136, 137, 150] have shown that several substances of slight or totally-negligible *nutritive* value are capable, of profoundly modifying the relative velocities of different types of growth when administered to animals in unusual amount. Such substances are, for example, lecithin, cholesterol, and the complex phospholipin "tethelin," which I have isolated from the anterior lobe of the pituitary body.[122,124,128,129,134,141]

Several characteristics serve to distinguish these substances from the substrates of growth to which reference was made in the preceding section. In the first place, they affect growth profoundly when *superadded* to an already abundantly varied and sufficient diet. The essentiality of lysin for growth, for example, is only revealed by administering to the animals a diet which is deficient in lysin. Once the necessary minimum has been supplied which is needed to maintain the equilibrium between tissue-lysine and circulating lysin,[153] the excess no longer affect the growth of animals in any striking manner. The reverse is the case with cholesterol or tethelin. When minute amounts (40 milligrams per day of cholesterol or 4 milligrams per day of tethelin) are added to an abundant and varied diet and administered in this fashion to mice, characteristic modifications of growth occur which unmistakably indicate disproportionate development of certain tissues.

It is furthermore characteristic of the *catalyzers* of growth, as distinguished from the *substrates* of growth, that they affect specific tissues primarily and that different tissues or the same tissue at different stages of its development, may be acted upon in diverse ways by the same catalyzer. Thus, cholesterol very strikingly accelerates the growth of carcinomata,[18, 123] and the rate of division of paramecia.[15] Certain of the tissues of mammals are retarded in their growth by cholesterol, possibly owing to the favor extended to other tissues, since the early growth of white mice is decidedly retarded by cholesterol, although at a later stage (succeeding puberty) their growth is accelerated, so that the outline of the resultant growth curve is totally different from that of the normal curve.[123] Lecithin, on the other hand, retards the rate of multiplication of paramecia.[15] while to an equally striking degree it accelerates the growth of tadpoles.[63, 66] In the effect of lecithin upon tadpoles, we have a very interesting illustration of the diverse actions of the same substances upon the growth of different tissues, for while, as stated, lecithin accelerates the growth of tadpoles in weight and linear dimensions, it inhibits the multiplication of the pigment-cells in the skin, with the result that the animals which receive lecithin are very lightly pigmented in comparison with normal tadpoles of the same age.

Tethelin accelerates the growth of epithelial tissues (skin tissue and carcinoma), while, like cholesterol but in much smaller doses, it retards the growth of young mice (fifth to fifteenth weeks) indicating that the growth of certain tissue-elements is retarded, possibly owing to the unequal favor extended to epithelial and bony tissues. At a later period (subsequent to puberty) the growth of mice is accelerated, so that the form of the growth-curve represents a characteristic distortion of the normal curve. The "bodily density" of the adult tethelin-fed animals is unusually high, the linear dimensions being small in comparison with their weight, a phenomenon which is possibly due to the acceleration of the completion of the skeletal framework and postponement of the development of the soft tissues. The favorable action of tethelin upon the development of skin and bone are strikingly reminiscent of the hypertrophy of the epidermis, hypertrichosis and enlargement of the extremities of the bones which are such notable features of acromegaly.[29, 122, 128]

We thus see that the growth catalyzers, unlike the growth-substrates, display a certain degree of tissue-specificity, affecting different cell- or tissue-types not merely in differing degree but in differing manner.

Still another distinction which obtains between the substrates and the catalyzers of growth is the unmistakable tendency of the ultimate equilibrium to attain the same or approximately the same level in the presence of excess of the catalyzer as in its absence. The older animals which have received excess of cholesterol or tethelin in their diet approximate more or less in weight to normal animals of like sex and age,* although the growth-curve representing the stages by which they attain this ultimate condition is totally unlike the normal. The behavior of growth-catalyzers, therefore, remind us of the "typical" catalyzers to which we referred above. The growth-substrates, on the contrary, if deficient in amount, determine the attainable development with absolute finality, just as the amount of cane-sugar which is subjected to the action of acidulated water determines with absolute finality the yield of invert-sugar which will be obtained.

A further analogy between the growth-catalyzers and the "typical" catalyzers is that which is afforded by the fact that despite the marked acceleration of pre-established carcinomatous growth which cholesterol or tethelin are able to cause, it is impossible, even by prolonged administration of these substances, to *initiate* carcinomatous growths in animals which have not been inoculated with carcinomatous tissue. Evidently these substances are accelerators but not initiators of the growth-process, and resemble other catalyzers in being able to accelerate reactions which are already occurring in some measure but unable to initiate reactions which would not occur, however slowly, in their absence.[99]

The existence of a variety of growth-catalyzers having more or less specific relations to definite types of tissue may therefore be regarded as established. The specificity of their action and the variety of parts played by the various endocrine organs in development rather invite the supposition that the several endocrine organs which control development each supervise and control the growth of particular groups of tissues. We are reminded of the multiplex character of the growth-process in mammals, as manifested by the presence of three distinguishable cycles of growth in the curve of complete development.

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* Phenomena of senescence may prevent absolute identity of ultimate development from being attained. Furthermore, the disproportionate development of certain tissues, for instance the skeleton, may mechanically inhibit the ultimate normal development of others.

Nevertheless, underlying and modifying all of the special instances of growth-acceleration or retardation which have been traced to Endocrine activities in the higher animals, must be a much more generalized, and therefore more fundamental mechanism of growth-regulation, which governs the growth and ultimate dimension of all cell-communities. This mechanism arises, as we have seen, from the control of the rate of growth of all cells by a "master reaction" or specifically slowest process, which is autocatalysed.

THE ENERGY EQUIVALENT OF GROWTH

The storing up of tissue-substance possessing a definite calorific value necessarily results in the retention by the growing animal of a proportion of the energy-value of its food. Furthermore, a considerable proportion of the heat-value of the diet, varying with the animals' age and rate of growth, is additionally consumed and dissipated in performing the work of storage. This is doubtless attributable to the fact that at all stages of growth, as at all stages of any chemical transformation, the forward and reverse reactions are proceeding side by side. In growth, the products of the reverse reaction (tissue-degradation) are not in general utilizable for the forward reaction (tissue-synthesis) so that their energy-value is consumed and dissipated in the form of heat, mechanical work, and the energy-values of excreta. Hence, we find that the slower the accretion of tissue in a given species of animal the greater the energy consumed per kilo of tissue built up, since the reverse reaction in such a case is proceeding for a longer time and more rapidly.[4, 140]

The following are illustrative results which were obtained by Aron.

TABLE 1.—GROWTH OF DOGS

Animal number	Calories consumed in fifty days	Increase in weight in fifty days	Calories consumed per gram of tissue increase
B	19,950	1,570	12.7
C	13,925	1,000	13.9
VIII	9,500	780	16.4
XII	10,750	838	15.6

From these results it is clear, as Aron points out, that an animal gaining 1000 grams during fifty days needs fewer calories for this gain than one gaining 1000 grams in one hundred days, the reason being, as indicated above, that in the first instance the animal needs to be "maintained" for only one half as long as in the latter. The following are comparable observations made by Aron upon Filipino children:

TABLE 2.—MARIA INOCENCIO

From week	To week	Number of days	Increase in grams			Calories	
			From—	To—	Per day	Per day	Per kilo
21	26	35	3500	3600	3	350–375	100–105
26	31	31	3650	4225	17	450	115–120
31	35	28	4225	4811	21	500	125

TABLE 3.—MIGUELO PRIEGA

From week	To week	Number of days	Increase in grams			Calories	
			From—	To—	Per day	Per day	Per kilo
4	9	35	3550	4175	17	350–400	100
9	13	28	4175	4850	24	450–475	105

Hence during the entire period of the investigation Maria Inocencio increased in weight at the rate of 14 grams per day and consumed an average of 450 calories per day and 115 calories per kilo. Miguela Priega, on the other hand, increased in weight at the rate of 21 grams per day and consumed about the same number of calories per day and a considerably smaller number per kilo.

According to Rubner[144]* the energy consumed per kilo in doubling the birth-weight of animals is always very nearly the same, excepting in the case of man, namely about 4000 calories. The following data are presented by Rubner in support of his thesis:

TABLE 4.—ENERGY-CONSUMPTION PER KILO IN DOUBLING THE BIRTH-WEIGHT

SPECIES	ENERGY-CONSUMPTION
Horse	4,512
Cow	4,243
Sheep	3,926
Hog	3,754
Dog	4,304
Cat	4,554
Rabbit	5,066
Man	28,864

The generalized form of this relationship would be

$$\frac{E}{x} = a \log x + b \qquad (8)$$

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* *Cf.* also, Wilson.[161]

where E is the energy-consumption, x the weight of the animal and a and b are constants which are independent of the species (except man). Doubling of the weight would obviously always add an equal amount to the quotient $\frac{E}{X}$, that is to the total energy-consumption per kilo. This leads to the differential equation

$$\frac{dE}{dx} = \frac{E}{x} + a \qquad (9)$$

which means that the consumption of energy per unit of tissue accretion increases in proportion to the energy which has already been consumed in reaching the weight to which this unit of tissue is added. This obviously corresponds very well with the facts ascertained by Aron. It is, however, probable that Rubner's law is not generally applicable, but that it holds good only in the earlier stages of growth, for unless some factor varying with the time be superadded to equation (8) it would lead to the absurd conclusion that an adult animal ceases to consume any energy at all. Rubner's law, therefore, only partially expresses the facts, and is at variance with his further generalization that the energy-consumption of animals per kilo, for the duration of life after attainment of maturity, is approximately the same for all species,[141] man, again, affording an exception to the rule.

The heat production of infants at various ages is thus summarized by Murlin.[90]*

Table 5.—Heat Production of Infants, Recently Fed and Sleeping

Age	Per Kilo and Hour	Per Square Meter of Surface and Hour
Birth	1.87	25
2 to 4 months	2.38	35
6 to 12 months	2.45	42

Under-fed and atrophic infants produce more heat than this, while over-weight infants produce less.

It must be remembered, however, that these figures are subject to considerable modification by a variety of factors, among which the type and quantity of clothing worn, and the temperature of the surrounding atmosphere are perhaps the most important.[107]

THE PHYSICAL MANIFESTATIONS OF GROWTH

The First or Infantile Growth-cycle

Prenatal Growth.—The determination of the time-relations of growth during the early months of pregnancy is beset by the same difficulties which attend the determination of the period at which development begins. The uncertainty attaching to our estimate of the age of the fetus necessarily vitiates the accuracy of our growth-diagram. Moreover, this inaccuracy is increased, if at the time we are unable to determine accurately the length of the period of development which the fetus has undergone. Consequently our estimate of the weight or length of the human fetus at various periods of the intra-uterine life is very inexact during the early months of pregnancy. These estimates, however, become increasingly more accurate as we approach the termination of gestation so that the errors in the estimate of the period of gestation become a less important proportion of the age of the fetus.

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* *Cf.* also, Howland.[59]

According to Zangemeister,[162] the average length and weight of the human fetus in the various lunar months of pregnancy are as follows:

Table 6.—Age and Dimensions of the Human Fetus

Month	Length, centimeters	Weight, grams	Monthly increment in weight, grams
1	0.7	1.0	
2	2.5	2.5	1.5
3	9.0	12.4	9.9
4	13.4	89.8	77.4
5	18.9	252.7	162.9
6	31.6	795.5	542.8
7	34.5	1066.0	270.5
8	39.3	1540.1	474.1
9	45.5	2243.3	703.2
10	49.9	3242.4	999.1

Table 7.—Age and Dimensions of the Human Fetus

Month	Length, centimeters	Weight, grams	Monthly increment in weight, grams
4	10–17	30–120	
5	17–27	139–350	109–230
6	27–34	400–800	261–450
7	35–38	820–1200	420–400
8	39–43	1220–1620	400–420
9	44–48	2100–2700	880–1080
10	48–56	2800–5500	700–2800

This may be compared with the following estimates by Daffner:[30] and, with the following estimates by Haase, Schroeder, Ahlfeld, Fehling and Gönner:[149]

TABLE 8.—AGE AND DIMENSIONS OF HUMAN FETUS

Month	Length, centimeters	Weight, grams	Monthly increment in weight, grams
1	1		
2	4		
3	9	25	
4	16	75	50
5	25	250	175
6	35	750	500
7	42	1250	500
8	45	1800	550
9	48	2500	700
10	50	3000	500

The discordance between these various estimates, made upon similar racial material is eloquent of their inaccuracy. We must conclude, therefore, that the estimates, especially those of weight, are possessed of only qualitative value. In general, however, the various estimates taken together reveal the fact that the growth in utero is part of a single growth-cycle, being interrupted by no pause or period of slackened growth, and that the velocity of growth (as indicated by the monthly increment in weight) increases continuously, reaching a maximum just before delivery.

I have sought to determine with somewhat greater precision the later portions of the pre-natal curve of growth from the weights of infants born at varying periods. Then in order to test the reliability of this method of procedure, I have also determined the weights of infants born somewhat later than the normal period.[116] Since this latter curve is identical with the continuation of the normal curve of extra-uterine growth that begins with the time of birth, we have reason to infer that the curve determined by the weights of prematurely delivered, but otherwise normal children, represents the further continuation of the same normal curve of growth backwards into the intra-uterine period.

The data were exclusively obtained from the "The Queen's Home," a maternity hospital in Adelaide, South Australia, and cover the years 1909–1913. Only those data were considered in which the period of gestation, reckoned from the date of the last menstruation, was definitely known. All infants stated to be suffering at birth from syphilitic infections, deformities, etc. and all infants who died within one week after delivery were excluded. The infants delivered by mothers who were suffering at the time of delivery or prior thereto from zymotic disease or other pathological conditions of a serious nature were also excluded.

The following (Table 9) are the results obtained for males; all infants born between 275 and 285 days after the onset of the last menstruation are tabulated as having been born at 280 days, all between 285 and 295 days as having been born at 290 days, etc. Those born upon a limiting period separating two classes (*e.g.* 285 days) are included in both classes (*e.g.*, 280 and 290).

TABLE 9.—MALES. (UNCORRECTED DATA)

Days pregnancy	Number of infants	Average weight in ounces*
190	1	27
200	0	
210	1	54
220	0	
230	0	
240	1	123
250	2	117
260	22	119
270	38	121
280	79	127
290	78	130
300	16	139
310	9	138
320	3	123
330	1	152
340	0	

A general tendency for increasing weight at birth to accompany increasing length of pregnancy is evident, but this becomes still more striking on *correcting* the above figures in the following way. The *most probable* error in the estimation of the period of pregnancy is that of *one month*. Hence, I assume that all periods of gestation which culminate in the delivery of infants weighing *less* than the uncorrected average for those born thirty days earlier, or *more* than the uncorrected average for those born thirty days later, are erroneously estimated. Infants delivered in these cases are, therefore, excluded. In this way we also exclude probably the majority of crypto-syphilitic infants born at the later periods of gestation.

The following, (Table 10) are the *corrected* results for males. This table excludes those born before 260 or after 310 days, since they are too few in number and possibly represent either pathological or erroneously estimated gestations.

The data for the 280-day infants were not corrected for three reasons, *firstly*, because the 280-day group is the group nearest to the mean, the mean period of gestation for male infants (*cf.* below) being 282.5 days, *secondly*, because the average weight of the 280-day infants

* I use the ounce avoirdupois (1 ounce = 28.34 grams) as a unit of weight because, in the first place the weights of the infants were actually measured in terms of this unit and, in the second place, it is a unit of very convenient dimensions for this purpose.

(127 ounces) is the nearest to the average weight of *all* the infants (127.3 ounces), and, *thirdly*, because errors in the estimation of this period would obviously tend to cancel one another.

TABLE 10.—MALES. (CORRECTED DATA)

Days pregnancy	Number of infants	Average weight in ounces
260	16	111
270	34	117
280	79	127
290	60	137
300	13	145
310	6	146

The following are the corresponding figures for female infants:

TABLE 11.—FEMALES. (UNCORRECTED DATA)

Days pregnancy	Number of infants	Average weight in ounces
190	1	39
200	2	59
210	0	
220	1	83
230	2	90
240	3	95
250	6	97
260	10	111
270	32	113
280	80	117
290	86	125
300	31	129
310	14	130
320	3	127
330	1	134
340	0	

TABLE 12.—FEMALES. (CORRECTED DATA)

Days pregnancy	Number of infants	Average weight in ounces
250	6	97
260	8	105
270	27	108
280	80	120
290	70	130
300	25	133
310	11	138

These figures show perfectly clearly a regular and uninterrupted increase in weight during the last eight weeks of gestation. The average rate of increase throughout the period investigated is 21 ounces (595 grams) per month for the males and 20 ounces (567 grams) per month for the females. There is no evidence of any fluctuation of growth-velocity such as would indicate the participation of more than one growth-cycle. We may therefore infer that the later months of development represent the continuation *in utero* of the first extra-uterine growth-cycle.

The Duration of the Period of Gestation.—From the data cited in Tables 10 and 12 on page 471 it is possible to construct a curve displaying the intra-uterine growth of infants from the 250th day of gestation until the 310th day. In order to determine which portion of this curve represents *normally* intra-uterine growth and which portion represents normally extra-uterine growth, however, it is necessary to determine with some exactitude the mean length of the period of gestation for man.

It is customarily assumed [158] that the normal duration of pregnancy is 280 days, reckoned from the first day of the last menstrual period. Hecker [30] has determined the duration of pregnancy in 109 cases with the following results:

TABLE 13

DAYS PREGNANCY	PERCENTAGE OF DELIVERIES
258	0.92
265	4.60
272	14.72
279	35.88:—Mode
286	23.00
293	12.88
300	5.52
307 314 321	0.92

The *Mode*, or period of greatest frequency of delivery, obviously coincides very closely with the usual estimate of 280 days.

From a statistical study of 511 normal confinements of South Australian Females,[118] of which 247 yielded male infants and 264 female infants, I have computed the mean length of periods of gestation yielding males to be 282.5 days with a "probable error" of 0.55 days and the mean length of periods of gestation yielding females to be 284.5 days with a "probable error" of 0.57 days. The distribution of the deliveries is shown in the following table:

TABLE 14

Period of gestation in days	Percentage of 247 male infants born at the designated period	Percentage of 264 female infants born at the designated period
240	0.0	1.1
250	0.8	2.3
260	8.9	3.8
270	15.4	12.1
280	32.0	30.3
	Mode	Mode
290	31.6	32.6
300	6.5	11.4
310	3.6	5.3
320	1.2	1.1

From these results we may infer that there is only *one* period, the "normal" period, at which the percentage of infants delivered by normal mothers attains a maximum. The "frequency-curve" which illustrates the distribution of deliveries among the various periods of gestation on either side of the mean is obviously unimodal. In the guinea-pig, on the contrary, it is distinctly bimodal. On tabulating the percentages of deliveries at different periods of gestation in this animal[109, 110] *two* groups of maximum frequency are seen to occur, a smaller "premature" group rather definitely situated and a larger "normal" group separated from the former by a period in which deliveries are relatively infrequent. This phenomenon is attributed by Read to the fact that intra-uterine growth in the guinea-pig involves the completion of one cycle of growth and the initiation of a second and that the "premature" group of deliveries occurs at the termination of the first cycle. The unimodal frequency-curve of deliveries in man, therefore, confirms the evidence: (1) that there is no junction of growth-cycles in the later months of intra-uterine development, and (2) that in man the greater part of intra-uterine growth is comprised by the first portions of the growth-cycle which is completed during the first year of extra-uterine life.

Bodily Dimensions at Birth.—The weight of the average infant at birth may be regarded, in view of the comparative invariability of the average duration of gestation, as the weight at a period of approximately 280 days after the initiation of development.

The weight of the infant at birth is very strikingly influenced by a variety of factors, among which may be especially mentioned the nutrition of the mother,[91] the number of previous pregnancies, sex, race, and environment. According to Fourmann,[76] each successive pregnancy leads to an average increase of 75 grams (2.65 ounces) in the weight of the child at delivery. The effect of the first pregnancy is more striking than that of subsequent pregnancies, as the following figures for Danish infants show:[52]

Table 15.—Average Weight of Infant at Birth

Pregnancy	1833 males, ounces	1617 females, ounces
First	116.4	113.1
Second	121.1	118.5
Third	122.9	116.9
Fourth	123.4	118.9
Fifth	125.8	121.6

The influence of race upon the weight at birth is shown in the following table:

Table 16.—Average Weight at Birth

Race	Males, ounces	Females, ounces	Investigator
American (New England)	120.8	115.7	Bowditch[14]
English (London)	116.8	113.2	Pearson[102]
Danish	123.0	115.7	Heiberg[52]
German (South)	122.1	113.7	Fourman[76]
Russian (North)	114.0	111.5	Tschepourkovsky[152]
Japanese	103.7	98.1	Miwa[76]

The British Anthropometric Committee[3] reports that the average weight at birth of 451 male infants born in London and Edinburgh is 113.6 ounces, while that of 466 female infants is 110.4 ounces. Through the courtesy of Drs. Smallwood Savage and Elsie M. Humpherson I have been furnished with the weights of one hundred male and one hundred female infants at birth, chosen without selection, from the records of normal full-term deliveries in the Maternity Hospital of Birmingham, England. From these data I find that the average weight of male infants at birth in Birmingham is 114.9 ounces, while that of female infants is 113.5 ounces. In South Australia, however, the average weight at birth of 208 male infants, delivered after normal periods of gestation, was found to be 127.3 ounces, that of 227 female infants being 121.3 ounces.

From these figures emerges the striking fact, that South Australian infants weighed from 8 to 10 ounces more at birth than infants born in Great Britain. This fact is remarkable because, according to an article on the "People of Australia" contributed by the Commonwealth Statistician, G. H. Knibbs, to the Federal Handbook on Australia issued in 1914 by the British Association for the Advancement of Science. "The Australian people, with regard to racial constitution, are virtually British, as the following figures from the last census show, and it may be added that the descendants of other European races disclose but small differentiation from their fellow citizens of British origin. The percentages of the principal races represented are as follows:

"Australian born 82.90 per cent. natives of United Kingdom 13.37; of New Zealand 0.72; of Germany 0.75; of China 0.47; of Scandinavia 0.33; of all other places 1.46; that is to say, at the date of the census, 1911, no less than 97 per cent. had been born either in Australasia or in the United Kingdom."

"The evolution of the Australian people, therefore, may be regarded as that of the British people under changed climatic, social, and economic conditions."

The results observed cannot be due to any racial selection among the immigrants from the British Isles who have given rise to the population of Australia. In the first place, there is no evidence that such selection has occurred to any greater extent than it has, for example, in London, whose very great increase in population during the past century has been contributed by all parts of the British Isles; and in the second place there is no evidence of the existence of a race in the British Isles which is in any noteworthy degree superior in physical dimensions to the average inhabitant of England.[3] We can only infer, therefore, that the superior weight of the Australian infant at birth is attributable to the factors enumerated by the Commonwealth Statistician, namely, the change in climatic, social, and economic conditions. The climate is much less rigorous than that of England. Food is cheaper in proportion to income, or, when equal in price, it is better in quality; and the social and economic conditions are so far an improvement upon those prevailing in England, that whereas women of the laboring and lower artisan classes in England have frequently to supplement the family income by their own exertions, those of the corresponding classes in Australia as a rule confine their physical activities to the management of their households and families. This condition of affairs, quite apart from the possible direct effects of unsuitable physical labor upon the mother, must have important indirect effects in ameliorating the nutritional and hygienic conditions within the household. These conditions, therefore, taken as a whole, may be conceived as having an appreciable pre-natal effect upon the growth of children. Evidence substantiating this point is disclosed, on the one hand, by the investigations of Pinard, who has shown that the rest and improved nutrition of hospital life during the whole or a part of the period of pregnancy, causes a notable increase in the average weight of infants delivered by working mothers,[91] and on the other hand by Prochovnik who has shown[91] that the size of a child at delivery may be definitely reduced by restricting the diet of the mother.

The *length* of the infant at birth is also influenced by race and sex as the following figures show:

TABLE 17.—AVERAGE LENGTH AT BIRTH

Race	Males, millimeters	Females, millimeters	Investigator
English	496	491	Roberts[111]
French (Paris)	499	492	Mies[88]
Belgian	500	494	Quetelet[108]
Russian (North)	505	495	Tschepourkovsky[152]
South Russian Jews	508	500	Weissenberg[156]
German	512	503	Daffner[30]

Post-natal Growth.—Data concerning the growth of infants during the first year succeeding birth are exceedingly abundant, but, unfortunately, the data most readily accessible are frequently of very little value. Anyone who looks into the methods of compilation that are commonly employed will readily perceive the numerous sources of error which vitiate a large proportion of observations of this type. In the first place, the sexes are very frequently grouped together. That such a practice is misleading is amply shown by the above-cited investigations on the influence of sex upon the weight at birth. In the second place, the weighings are not infrequently performed carelessly on inaccurate balances by persons to whom accuracy in this connection appears superfluous; the weighings are generally, and necessarily, made at infrequent and irregular intervals. Finally, in constructing a normal standard, the data are frequently rendered still more questionable by the inclusion of sickly, diseased, or abnormal children, or infants who are the fruit of abnormal pregnancies. When we make due allowance for these and other sources of error, the accessible and reliable data become surprisingly few and fragmentary.

In attempting to obtain more reliable data I have utilized the records which have been collected in recent years in England and Australia by the "Schools for Mothers."[116, 117, 126] These institutions offer instruction to mothers regarding the feeding and care of their infants at a nominal charge. In South Australia the Registrar of Births reports at frequent intervals the births which have occurred in the neighborhood of the "Adelaide School for Mothers Institute." A nurse in the employ of the Institute then calls upon those mothers known to be more or less needy in circumstances, who are likely to have insufficient medical advice, and proffers them the services of the Institute. The infants are voluntarily brought there by the mothers upon certain days when the nurse is in attendance. The infants are weighed without clothing by the nurse, and the weight and date with other important information, such as the infant's food, illness, etc., are noted upon a card bearing the infant's name and sex. The card is then placed on file for record. The children who are brought to the institute belong, for the most part, to the laboring and lower artisan classes, and include in their number a large proportion of sickly infants, because mothers who cannot well afford private medical care for their children are quick to appreciate and take advantage of the benefits bestowed by the Institute.

The following data (Tables 18 and 19), computed from the records of this Institute, were accumulated in the years 1910–1913. All infants suffering from definite ailments or requiring medical attendance were excluded from these computations. When babies who were otherwise normal, contracted zymotic diseases, such as mumps, measles, etc., the weights included in the data were those taken immediately preceding or accompanying recognition of the disease. All subsequent weighings were rejected, regardless of whether or not the disease, after its recognition, affected the baby's weight.

On the whole, the data were obtained from repeated weighings at irregular intervals of 159 "normal" infants, classified as follows:

Breast-fed males	63	Total males	90
Bottle-fed males	27		
Breast-fed females	43	Total females	69
Bottle-fed females	26		

The "breast-fed" classes include all infants stated to have been breast-fed, irrespective of the period during which they were so fed. Infants are considered to have been bottle-fed when there is no record of breast-feeding upon their cards. The balance employed for weighing was accurate to within one ounce. The following are the summarized data:

TABLE 18.—AVERAGE WEIGHT IN OUNCES OF MALES

Age in months of 30 days	Breast-fed	Bottle-fed
1	155	117
2	187	141
3	206	169
4	224	193
5	254	226
6	270	242
7	287	267
8	300	329
9	311	280
10	326	298
11	333	322
12	330	335

The superiority of the breast-fed children, which has so frequently been commented upon by numerous observers, is here again strikingly revealed.

TABLE 19.—AVERAGE WEIGHT IN OUNCES OF FEMALES

Age in months of 30 days	Breast-fed	Bottle-fed
1	153	120
2	168	137
3	188	156
4	209	179
5	224	184
6	253	198
7	263	212
8	270	239
9	300	259
10	315	252
11	335	265
12	345	288

In the introductory part of this chapter I pointed out that the relationship between weight and time for any single growth-cycle is the same as that which subsists between the extent of transformation and the time in an autocatalyzed chemical reaction, that is, a reaction one of the products of which accelerates it. The formula expressing this relationship is:

$$\log \frac{x}{A - x} = k(t - t_1).$$

Where A is a constant (= the maximum weight attained by the particular growth-cycle under consideration), t_1 is a constant (= time at which the cycle is half-completed) and $K = kA$ where k is the specific velocity-constant of the process (see equations $1 - 7$).

We may, therefore, employ this formula as a means of estimating from the observed curve of growth and correcting slight accidental fluctuations in the average data. We shall employ for this purpose only the data for breast-fed infants, since these may safely be presumed to be the most "normal" data available.

The various constants in the equation of auto catalysis are computed from all of the observations by the method of least squares.*

In this way we find that for the first nine months of the extra-uterine growth† the equation for the growth-curve for South Australian males is expressed by the formula:

$$\log_{10} \frac{x}{341.5 - x} = 0.136\ (t - 1.66) \tag{10}$$

t being reckoned in months from birth and x in ounces.

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* For the methods of computation employed and tables for the facilitation of the incidental calculations the reader is referred to my "Tables for the Computation of Curves of Autocatalysis, with especial reference to Curves of Growth," University of California Publications in Physiology, 4 (1915) Nr. 21.

† Only the data for the first nine months are employed in computing the constants, since in later months the effect of the second growth-cycle becomes more or less apparent.

In the following Table (20) the observed weights at the various ages are compared with those calculated from the above formula.

TABLE 20.—WEIGHT IN OUNCES OF MALES

Age of infant in months	Observed	Calculated	Δ = deviation from calculated value
0	127	127	±0
1	155	156	−1
2	187	180	+7
3	206	206	±0
4	224	230	−6
5	254	254	±0
6	270	273	−3
7	287	288	−1
8	300	301	−1
9	311	311	±0
10	326	319	
11	333	325	
12	330	330	

The equation for the curve of growth for the first nine months of the extra-uterine life of South Australian females is found to be:

$$\log_{10} \frac{x}{350 - x} = 0.111(t - 2.47) \tag{11}$$

In the following table the observed weight at various ages are compared with those calculated from the formula:

TABLE 21.—WEIGHT IN OUNCES OF FEMALES

Age of infant in months	Observed	Calculated	Δ = deviation from calculated value
0	121	121	±0
1	153	142	+11
2	168	164	+4
3	188	187	+1
4	209	209	±0
5	224	230	−6
6	253	249	+4
7	263	267	−4
8	270	282	−12
9	300	295	+5
10	315	305	
11	335	314	
12	345	321	

In both instances the agreement between theory and observation is extremely good, especially if we consider the comparatively small number of infants observed.

Having thus found an algebraical formula which adequately represents the post-natal growth of South Australian Infants, as determined from direct measurements at varying periods succeeding birth, we can now proceed with the aid of this formula to project the observed curve a short distance backwards and ascertain to what degree this exterpolated curve agrees with the curve of pre-natal growth determined by the measurement of the weight of pre- and post-maturely born infants at birth.

The mean period of gestation for South Australian male infants is, as we have seen, 282.5 days. In the Equation (10), therefore, which represents the post-natal growth of males, $t = 0$ when the infant has presumably lived 282.5 days of intra-uterine life. It is true that there is much doubt whether the period of gestation measured from the onset of the last menstruation represents the true period occupied by the growth of the embryo,[158] but this uncertainty does not attach in nearly the same degree to the estimation of *differences* between periods of gestation, with which we are solely concerned here. Taking, therefore, the value of $t = 0$ for the period of 282.5 days, and recollecting that $t = 1$ at 30 days, we find that male infants born, for example, at 260 days have been delivered 22.5 days or 0.750 month prior to the period defined by $t = 0$ in equation (10). In other words, in order to find by exterpolation from equation the "calculated" weight of an infant of this age, that is, the weight which it should have if intra-uterine growth were continued uninterruptedly into extra-uterine growth, we must insert the value $t = 0.750$ and calculate from the equation the corresponding value of x. Proceeding in this way, we obtain a series of "calculated" weights which should agree very closely with the weights actually determined by weighing infants born at the corresponding periods if intra- and extra-uterine growth are portions of the same growth-cycle. A comparison of the "calculated" and "observed" weights of male infants born at varying periods of gestation follows (Table 22), the "observed" weights being taken from Table 10 on page 471.

TABLE 22.—WEIGHT IN OUNCES OF MALES

Period of Gestation in days	t	Weight in ounces	
		Observed	Calculated
260.0	−0.75	111	110
270.0	−0.42	117	117
280.0	−0.08	127	126
282.5	±0.00	127	127
290.0	+0.25	137	134
300.0	+0.58	145	142
310.0	+0.92	146	151

The corresponding computations for females follow (Table 23). In this case $t = 0$ at 284.5 days. The "observed" weights are taken from Table 22 on page 480.

TABLE 23.—WEIGHT IN OUNCES OF FEMALES

Period of Gestation in days	t	Weight in ounces	
		Observed	Calculated
250.0	−1.13	97	99
260.0	−0.82	105	106
270.0	−0.48	108	112
280.0	−0.15	120	118
284.5	±0.00	121	121
290.0	+0.18	130	125
300.0	+0.52	133	132
310.0	+0.85	138	139

The agreement between the observed and calculated weights for both sexes is as close as could possibly be expected. From this we may infer, *firstly*, that the weights at birth of children born *after* the normal period are identical, within very narrow limits, with the weights which they would have attained at that time had they been born at the normal period, *secondly* that the post-natal growth-cycle as determined from weighings of infants of from 1 to 9 months of age is continued smoothly backwards into the pre-natal curve of growth, and *thirdly* that the post-natal loss of weight which is so general a phenomen is not a characteristic of the infantile growth-process itself, but an accident attributable to the mechanical and nutritional shock of delivery (see also section VII).

The medical advisers of the various "child welfare leagues" and "schools for mothers" in Great Britain appear usually to regard the so-called "Newman Standard" as an accurate representation of the growth of British infants during the first two years succeeding birth. In fact, charts representing this standard are not infrequently found displayed in the offices of these organizations or even plotted upon the growth-charts of the infants under their care, for purposes of comparison. As I was unable to ascertain the source of this standard even after inquiry among the officials and medical advisers of these institutions in London, I addressed myself directly to Sir George Newman, who very kindly replied, referring me to his work on Infant Mortality.[91] Although charts of the "standard" are supplied in that work, I find, that the source of the measurements is nowhere clearly indicated, unless indeed it be upon page 303, where the author states "Dufour's Standard has been used in the Finsbury Depôt as in the French Depôts, and the charts appearing in the present volume are drawn to that scale."

It would seem, therefore, that the standard of infant growth employed in England originated in France. Having regard to the marked influence of race and environment upon pre-natal growth, which I dwelt upon in the preceding section, it appeared to me very likely that a French standard would prove untrustworthy when applied to the growth of normal British Infants. Moreover, the Newman Standard makes no distinction between the sexes, whereas, as the above-cited data and many observations upon animals[34, 89, 100, 120] show, the growth-curves of the two sexes, even during the first growth-cycle, differ from one another very considerably. That marked discrepancies exist between the actual weights of British Infants and the Newman Standard weights has been pointed out by Pooler.[105]

In order, therefore, to construct this portion of the growth-curve of the inhabitants of Great Britain, it appeared necessary to obtain fresh estimates of the average weights of children at monthly intervals during the first year succeeding birth. Accordingly, in the spring of 1914, I addressed myself to the medical advisers and other officials of the various child-welfare institutions in London, Leeds, and Bristol and through their courtesy, obtained accesss, to the very extensive data collected by these institutions during the execution of their activities. The data herein reported were obtained from the records of the Pimlico Road and Golden Square branches of the Westminster Health Society and the Chelsea Health Society in London and from the Leeds Babies Welcome. The data obtained from other cities proved too fragmentary to be utilized in statistical studies of this type.

In the case of the London institutions mentioned, I was given the opportunity of personally inspecting the methods employed in weighing and examining the children and in keeping their records. In certain institutions which I visited, no records of sex were kept. Therefore, their data could not be utilized. Other institutions weighed the infants only approximately. These data were likewise rejected. In the institutions mentioned, however, the sex of the infant is indicated upon the record, and the weights are recorded to the nearest ounce avoirdupois. The infants were voluntarily brought by their mothers to the offices, where a medical advisor, nurses, or other trained officials were in attendance. At each visit the weight and condition of the child were noted. The weights of all infants reported to be suffering from measles, whooping cough, chicken-pox, scarlet fever, diphtheria, pneumonia, bronchitis (unless specifically noted as "slight"), and marasmus were excluded on and succeeding the date upon which the condition was first noted. Data concerning twins and malformed children were likewise excluded. Furthermore, only children stated to be of British parentage on both sides and wholly or partially breast-fed were accepted as sources of data. The data reported are exclusively ante-bellum and were for the most part derived from records taken in the years 1911–1914.

The application of the autocatalysis formula to these data showed that the first nine months of the growth-curve of British male infants may be represented by the equation:

$$\log_{10} \frac{x}{318 - x} = 0.127(t - 1.4) \qquad (11)$$

t, as before, being measured in months of thirty days each and x in ounces avoirdupois. Inserting the observed valued of t in this formula and computing therefrom the corresponding values of x, we obtain a series of "calculated" weights corresponding to the various ages. In the accompanying table the observed and calculated values are compared, the "Newman Standard" weights being included in the fourth column.

TABLE 24.—WEIGHT IN OUNCES OF BRITISH MALES

Age in months	Weight in ounces		Newman Standard
	Observed	Calculated	
1	147	148	123
2	169	171	142
3	194	194	161
4	219	216	180
5	234	235	204
6	252	252	228
7	269	266	244
8	276	277	255
9	283	287	268
10	300	293	282
11	303	300	295
12	314	304	308

The equation representing the infantile growth-curve of British females proved to be:

$$\log_{10} \frac{x}{312 - x} = 0.106\ (t - 1.54) \qquad (12)$$

the comparison of theory and observation follows:

The agreement between the formula and the observations is all that could be desired. Such close agreement, in fact, has seldom been equalled amidst the glass ware of laboratories. The probable reasons for this surprisingly exact conformity to formulated values are to be sought in the excellent conditions of thermostasis, constancy of osmotic conditions, etc., under which reactions in living tissues take place and also in the statistical methods employed in obtaining the individual observations, which automatically exclude individual and accidental deviations from the average by mutual cancellation.

It will now be observed in passing that the Newman Standard weights are considerably too low even for the female infants.

TABLE 25.—WEIGHT IN OUNCES OF BRITISH FEMALES

Age in months	Weight in ounces		Newman Standard
	Observed	Calculated	
1	143	146	123
2	160	165	142
3	180	184	161
4	202	202	180
5	218	218	204
6	235	233	228
7	253	247	244
8	258	259	255
9	265	269	268
10	273	277	282
11	288	284	295
12	288	290	308

The foregoing data may be compared with those obtained by Schmidt-Monnard[145] for the growth of 1500 breast-fed infants in Frankfurt. The autocatalysis equation for the infantile growth-cycle in males (data for the first nine months only being employed in the computation of the constants) proves in this case to be:

$$\log_{10} \frac{x}{314.6 - x} = 0.142(t - 2.65) \qquad (13)$$

In the following table the observed and calculated weights are compared:

TABLE 26.—WEIGHT IN OUNCES OF SOUTH GERMAN MALES

Age in months	Average weight in ounces	
	Observed	Calculated
1	122	116
2	145	141
3	171	167
4	200	192
5	207	215
6	240	236
7	248	254
8	251	268
9	267	279
10	293	288
11	297	295
12	303	300

The equation for females is found to be:

$$\log_{10} \frac{x}{290.0 - x} = 0.156\ (t - 2.25) \qquad (14)$$

In the following table the observed and calculated weights of the female infants are compared:

TABLE 27.—WEIGHT IN OUNCES OF SOUTH GERMAN FEMALES

Age in months	Average weight in ounces	
	Observed	Calculated
1	114	113
2	141	138
3	169	164
4	191	189
5	207	211
6	227	230
7	242	245
8	245	257
9	261	266
10	266	273
11	268	278
12	274	282

Here the agreement between theory and observation is not quite so exact as in the case of the British infants, possibly because the criteria of normality applied to the infants from which the data were obtained were not so rigid. The agreement is, however, of a very satisfactory order, and it is evident, from the three groups of infants which we have reviewed that the curve of autocatalysis does faithfully represent, in all its essential features, the first year of extra-uterine and the late months of intra-uterine growth.

Influence of Race and Environment.—A comparison of the results enumerated in Tables 20 and 21 on p. 479 shows that the initial superiority in weight of British Infants born in Australa over British infants born in England is maintained throughout the first twelve months of extra-uterine growth. The origin of this superiority lies primarily in the fact that *A*, the constant expressing the maximal growth attainable by the cycle, is larger for Australian than for English infants.

Reverting to the analogy with bacterial multiplication, which was dwelt upon in the introductory portion of this chapter, we see that A is expressive of or proportional to the total mass of available nutrition, the "nutritional level," in other words, of the environment. For while it is true that the prime factor in inducing stoppage of growth in any cycle is the accumulation of the products of the process rather than the exhaustion of the materials for its continuance, yet, (as reference to equations 5 and 7 shows) the ultimate growth attainable in any cycle is nevertheless *proportional* to the totality of available foodstuffs. In the mammals this corresponds to the concentration of nutritive materials constantly maintained by the activity of the digestive organs in the blood and tissue-fluids, a concentration, which, under given environmental conditions, may be assumed to be approximately and in the long run constant. The probable mechanism which maintains this constancy of the available nutritional materials in the tissue fluids is indicated by the investigations of Van Slyke[153] and others, who have shown that the proportion of free amino-acid-groups unutilized by the tissues and stored as a reserve is characteristic of each tissue and maintained at a relatively constant level, notwithstanding the diversity of material absorbed from the digestive tract. That a similar equilibrium between tissues and tissue-fluids is also maintained for the carbohydrates is shown by the relative constancy, under normal conditions, of the blood-sugar content and by the fact that when the blood is robbed of sugar, as in Phloridizin glycosuria, the tissues immediately yield up sugar to the blood in the effort to maintain the normal equilibrium.

The value of A in the growth-equation, therefore, must be primarily determined by the average concentration of nutritional materials available for the growth or repair of cells. We should expect to find, therefore, that A is dependent to a large extent upon nutritional and other conditions constituting the environment of the growing animal.

The reverse is the case with the constant k (see equation 2, page 450), which is the specific velocity constant of the growth-process itself, *i.e.*, expressive of the velocity of transformation of unit mass of nutritional materials into tissue substance. This parameter of the growth-curve is internal rather than external in character and is expressive of the intimate nature of the growth-process itself, independently of the nutritional level of the tissues. We should expect to find, therefore, that the constant $k\left(=\frac{K}{A}\right)$ is dependent upon sex or race but not upon environmental factors.

In the following table the values of A and k for British Infants born in England and Australia and for South German infants are compared:

TABLE 28.—COMPARISON OF THE EFFECTS OF RACE AND ENVIRONMENT UPON THE PARAMETERS OF THE GROWTH-CURVE

	Males		Females	
	A	$k \times 10^6$	A	$k \times 10^6$
British (born in England)....	318.0	399	312	340
British (born in Australia)...	341.5	398	350	317
South German.............	315.0	451	290	537

It will be seen that the parameters are affected in the sense indicated by our theory by the factors of sex, race, and environment. While the value of A is not greatly affected by sex or by dissimilarity of race, since values obtained in the similar environments of Frankfurt and London are very similar, it is greatly affected by dissimilarities in environment, as a comparison of the values of A in Australia and in Europe shows. On the other hand, k is comparatively unaffected by environment, being practically identical for British males, whether born in Australia or in England, and very nearly the same for British females born in these two environments; whereas it is profoundly affected in magnitude by sex and race, as indicated by the marked difference in the values of k for males and females and for South-German as compared with British infants.

When it is remembered that these parameters are not calculated arbitrarily, but are computed by the method of least squares from all of the observations and therefore partake in some measure in the errors incident to the observations, it will be admitted, I think, that the above data afford a very striking confirmation of the correctness of the view that growth is determined by an underlying autocatalyzed chemical process. It is furthermore clear that the form of the curve of growth in infants is determined by two separate factors; the one, analogous to the absolute mass of reacting substances in a chemical reaction, being dependent upon environment and probably upon the abundance or deficiency of the habitual dietary; while the other, analogous to the specific velocity of a chemical reaction, is relatively, if not absolutely, independent of environmental or nutritional conditions, and, being expressive of the nature of the growth-process itself as distinguished from the availability of the materials for growth, is distinctively modified by race and sex.

Criteria of Normality.—The intimate dependence of the growth of normal infants upon environment, race, and sex at once reveals the fact that there is no single standard of infantile development which will be applicable to the average infant of either sex, of differing racial stock or to varying environmental conditions. It is clear that a growth-standard, even if it be regarded as applicable only to the average normal and not to individual normals, who deviate widely from the average, must be constructed with regard to the sex, race, and environment of the infants under consideration. It is evident, therefore, that a French standard can give us very little reliable information concerning the super- or subnormality of the British infant in comparison with the average; while a British standard would be of equally little value when applied to infants of Russian, Jewish, or Italian descent in New York. In America, especially, the problem of constructing a reliable standard average curve for the growth of infants is greatly complicated by the variety of racial types which may present themselves for advice or treatment at milk-depôts or clinics.

In practice, however, we really need something more serviceable than an average standard growth-curve, even though it be only adapted to the sex, race, and environment of the individual infant. As a matter of fact, it will at once be admitted by all who are engaged in practical work with infants that comparison of the growth-curve of an individual infant with a standard average curve yields little information of immediate practical utility that we could not derive from an examination of the individual curve alone. This is because we recognize that the *variability* of the growth of infants is so great, that perfectly normal children of like sex and race, growing under nearly identical environmental conditions, may differ widely and in opposite directions from the *average* normal standard. We clearly recognize in practice that a general "build" of healthy infants varies in fact, even more than the general build and weight of healthy adults.

The criterion of normality or abnormality upon which we rely in practice is in reality the *form* of the individual growth-curve rather than its deviation from any standard average. Provided the weight of the infant at birth is not excessively super- or sub-normal, we are satisfied if its curve of growth presents an even sweep of increments and is, on the whole evenly *parallel* with the normal standard.

There is, however, a tendency to be satisfied with a supernormality of weight which may be of negligible importance when compared with the standard average, but which, compared with the growth-level or "build" or the infant itself, may be just as ominous of impending disaster as a proportionate subnormality of an infant whose personal "build" is above the average.[107]

The growth-curve of apparently perfectly normal children, however, rarely takes place in one even sweep. As I have pointed out in the introductory part of this chapter, the curve of any individual child will usually show more or less marked irregular fluctuations, which are clearly departures from the autocatalytic curve representing the average growth of a large number of individuals. When such fluctuations are excessive, they are indicative of faulty physiological conditions, but, on the other hand, if we were to regard all such individual fluctuations as abnormalities, there would be hardly any infant who could be regarded as "normal." Evidently then, the problem of normality is quantitative rather than qualitative, so that what we need for practical guidance in individual cases is some measure of the limit of deviation from parallelism with the autocatalytic curve which may safely be regarded as normal. Such a measure of permissible individual deviation can be obtained by a study of the *variability* of the weights of normal infants at several periods of their development.

In any fortuitously selected group of animals or human beings, the individuals comprising the group will be found to vary in greater or lesser degree from the type or average which the group collectively represents. When a large proportion of the individuals comprising the group differ from the average to a considerable degree, we say that the group or type is highly variable, while on the other hand, when but few of the individuals comprising the group depart widely from the average, we consider the group or type to be but slightly variable.

The measure of variability which is commonly employed by statisticians is the percentage ratio of the "standard deviation" of the quantities measured to their average value (25, 81). The "standard deviation" is the square root of the mean square of the deviations of the individual measurements from the average. For example, if five measurements should yield the values 3, 4, 5, 6 and 7, the average value would be 5, the "standard deviation" would be

$$\sqrt{\frac{2^2 + 1^2 + 1^2 + 2^2}{5}} = 1.414,$$

and the variability would be

$$\frac{1.414}{5} \times 100 = 28 \text{ per cent.}$$

If, again, five other measurements should yield the values 13, 14, 15, 16, and 17, the "standard deviation" would be 1.414 as before, while the variability would be $\frac{1.414}{15} \times 100 = 9$ per cent. If, again, the measurements should yield the values 103, 104, 105, 106 and 107, the variability would be 1.35 per cent. In the first case, the objects measured are evidently very variable; in the second they are moderately variable; while in the third example they are only slightly variable. We have translated into quantitative terms the impression to which a comparison of the three sets of figures at once gives rise, but which, in the absence of some principle of precise computation, remains an impression and nothing more.

The "variability" of a quantity determined in this way is almost exactly the deviation from the average which one-third of the measurements display.

I have determined the variabilities at birth and during the first twelve months of extra-uterine growth of the weights of British infants, with the following results:

TABLE 29.—VARIABILITY OF BRITISH INFANTS

Age in months	Percentage variability of weight	
	Males	Females
0	13.2	12.5
1	17.0	14.4
2	16.4	15.0
3	15.8	15.6
4	15.9	15.0
5	14.7	14.5
6	15.1	13.4
7	14.9	14.6
8	13.1	14.0
9	13.8	14.0
10	13.4	11.6
11	15.3	12.5
12	12.6	11.9

There is a general tendency for variability of weight to increase with increasing velocity of growth and to decrease with decreasing velocity of growth[120, 126, 127, 151] so that any given group of infants above the average in weight will generally be found to be more variable in weight than the average, while subnormal infants are less variable than the average. On the whole, however, we may infer from the above table that the weights of two-thirds of British infants will at any time during the first twelve months of extra-uterine growth lie within 14 per cent. of those indicated by the standard average curve.

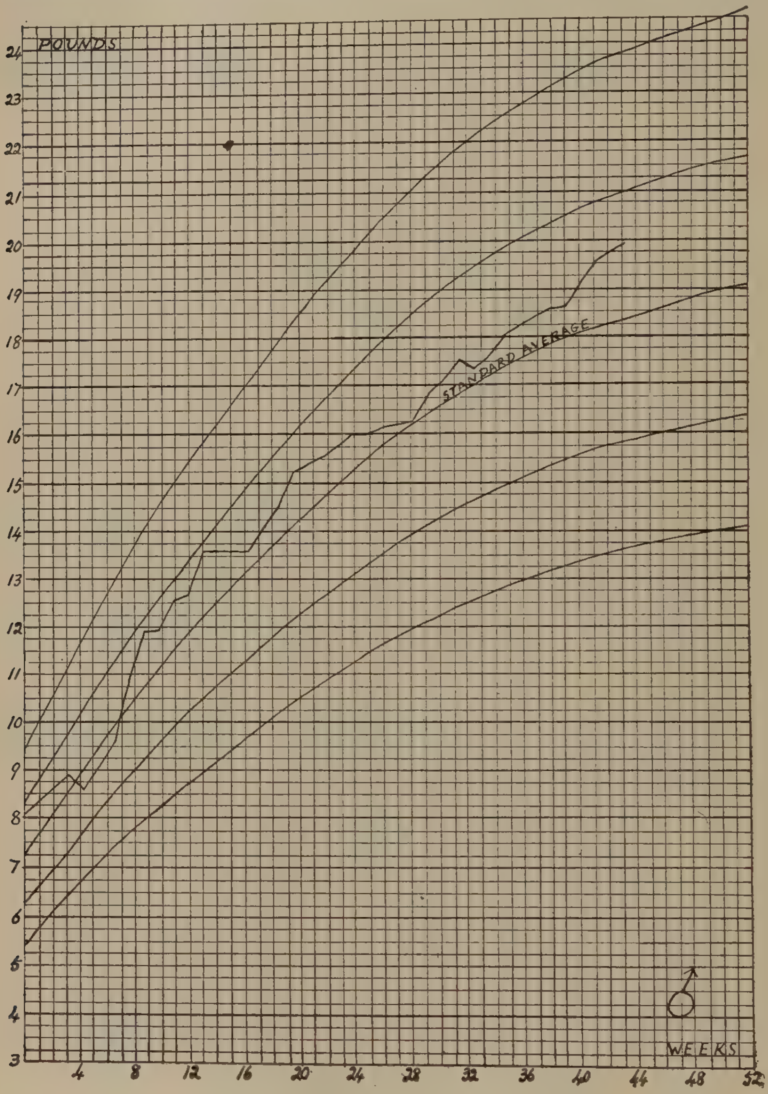

FIG. 191.—Growth-chart for male infants.

If, therefore, we construct a series of parallel curves, each of which differs by 14 per cent. from the adjacent curves, we may safely infer that *the growth curve of any individual normal infant should never cut two of these parallel curves*, or at least, that such a phenomenon should immediately attract attention and arouse suspicion of abnormal physiological or nutritional conditions.* In the accompanying figures are illustrated growth charts of this type for males and females, based

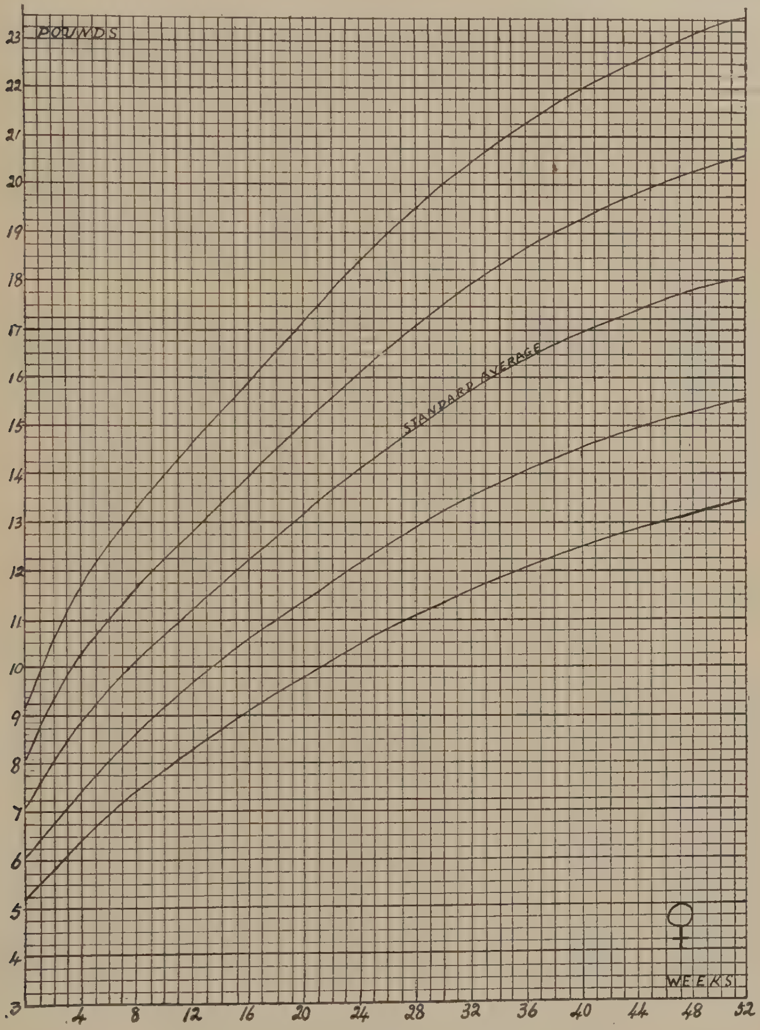

FIG. 192.—Growth-chart for female infants.

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* It is, perhaps, unnecessary to point out that such conditions may be prenatal, so that the cutting of two curves during the first few months after birth may, in such cases, merely represent restoration of "normal" equilibrium.

upon the average curve for the growth of British Infants. In order to illustrate the method of employing these charts, the growth curve of a normal infant weighed at weekly intervals is plotted upon the chart for males. It will be observed that although the growth-curve of this infant displayed considerable fluctuations from the "normal" autocatalytic curve, yet these fluctuations were never of sufficient magnitude to lead to the intersection of two of the parallel standard curves: thus, there was never any serious doubt of the approximate normality of this child's development. By the use of a chart of this description, we make allowance in a logical manner for the normal individuality of "build," while at the same time we are enabled with a sufficient degree of precision to distinguish fluctuations of development which are probably devoid of practical significance from those which are almost certainly indicative of conditions deleterious to the development of the child.

The Post-natal Loss of Weight in Infants and the Compensatory Over-growth Which Succeeds It.—It is a familiar fact that for a variable period, which in normal cases does not exceed one week, the majority of infants lose weight after birth. This is a phenomenon which is very generally observed after the birth of animals.[100, 109, 110] In the case of man it is usually attributed to the fact that for the first few days succeeding birth the child receives little or no nutriment.[16, 158] That this is probably not the only factor involved, however, is shown in the first place, by the fact that the post-natal loss of weight is usually much greater when the child is excessively large[158] and in the second that such loss occurs even in young guinea-pigs, which are born in such an adult condition that they are capable of feeding themselves entirely by the fourth day after birth. It must be admitted, however, that the power of these animals to nourish themselves at such an early date assists them to overcome a large part of the post-natal retardation of growth, for the retardation is relatively slight in guinea-pigs and frequently leads to an actual *loss* of weight only in the male.[89, 109, 110]

I have computed the average weights at birth and at one week after birth of a number of infants born at the end of determined periods of gestation at "The Queens Home" in Adelaide, South Australia.[94] The infants born in this institution are fed by the mother, when this is feasible, six hours after birth, and every four hours thereafter. If the mother's milk is insufficient a little water or milk diluted to one-fourth is given.

The following tables exhibit the relationship between the post-natal loss of weight at the end of the first week and the length of the period of gestation, which is estimated from the onset of the last menstruation. Those cases are excluded in which the infant weighed less at birth than the average weight of infants *born thirty days previously*, or more than the average of infants born thirty days later.[116] Periods lying between 265 and 275 days in length are recorded as periods of 270 days, and so forth; periods falling upon the limiting date separating two classes (*e.g.*, 275, days) are included in both classes (*e.g.*, the 270 and 280 day classes.)

TABLE 30.—MALES

Period of gestation in days	Average weight in ounces at one week after birth	Average weight of same infants at birth	Average loss (−) or gain (+) of weight in ounces
260	106	109	−3
270	114	119	−5
280	119	125	−6
290	137	141	−4

TABLE 31.—FEMALES

Period of gestation in days	Average weight in ounces at one week after birth	Average weight of same infants at birth	Average loss (−) or gain (+) of weight in ounces
260	98	97	+1
270	110	110	±0
280	118	119	−1
290	119	125	−6
300	119	122	−3
310	127	132	−5

It will be seen that these data display no very clear correlation between the magnitude of the post-natal loss of weight and the length of the period of gestation preceding birth, although there appears to be a certain tendency for infants born at the later periods of gestation to lose more heavily than those born after the briefer periods. This, as we shall see, is attributable to the fact that the infants born at the later periods are heavier and therefore larger than the infants born at the earlier periods.

The following tables exhibit the relationship between the post-natal loss of weight and the weight of the infant at birth, all infants weighing, for example, between 115 and 125 ounces at birth being regarded as having weighed 120 ounces at birth. Infants of which the weight at birth fell upon a limiting weight separating two weight-classes (*e.g.*, 115 ounces) being included in both classes (*e.g.*, the 110 ounce and 120 ounce classes).

It will be seen that there is a very clear correlation between the magnitude of the post-natal loss of weight and the weight (and, therefore, presumably the *size*) of the infant at birth. The infants weighing over 130 ounces at birth suffer especially, while infants weighing less than 110 ounces at birth, so far from losing weight during the first week after birth, frequently gain considerably. From this it would appear legitimate to infer that *mechanical shock during delivery* is an important factor in determining the post-natal loss of weight.

TABLE 32.—MALES

Weight at birth in ounces	Weight at one week after birth	Loss (−) or gain (+) in ounces
80	91	+11
90	86	−4
100	104	+4
110	108	−2
120	117	−3
130	128	−2
140	132	−8
150	144	−6
160	150	−10
170	160	−10

TABLE 33.—FEMALES

Weight at birth in ounces	Weight at one week after birth	Loss (−) or gain (+) in ounces
80	77	−3
90	94	+4
100	105	+5
110	108	−2
120	118	−2
130	125	−5
140	129	−11
150	138	−12

The average weight after birth of all the male infants (= 57) born after periods of gestation lying between 245 and 325 days was 121.4 ounces; the average weight of South Australian male infants at birth (93) is 127.3 ounces. Hence, the average observed loss of weight during the first week after birth of South Australian male infants is 5.9 ounces, or 4.6 per cent. of their weight at birth.

The average weight at one week after birth of all the female infants (= 79) born after periods of gestation lying between 235 and 325 days was 115.0 ounces; the average weight of South Australian female infants at birth is 121.2 ounces. Hence the average observed loss of weight during the first week after birth of South Australian female infants is 6.2 ounces, or 5.4 per cent. of their weight at birth.

From these figures it would appear that the growth of female infants is more retarded by birth than that of male infants. That this is not really the case, however, is shown by the following considerations:

It must be recollected that the above figures do not represent the whole of the loss of weight due to birth. At the time of birth the infant is growing rapidly, so that if it were not for the nutritional and mechanical shock of birth, the infant would *increase* considerably in weight during the first week of post-natal life. The *observed* loss of weight is, therefore, not the *actual* loss of weight. What this actual loss amounts to may be estimated to within a very close approximation by the following method:

I have shown above that the latter part of the prenatal and the first 9 months of the post-natal growth of South Australian male infants, may be represented very accurately by the formula:

$$\log_{10} \frac{x}{341.5 - x} = 0.136\ (t - .166)$$

where x is the weight of the infant and t is the time, measured in months of 30 days, which has elapsed since birth. Now at one week $t = 7/30 = 0.23$. Hence by putting $t = 0.23$ in the above formula, we can estimate what South Australian male infants would weigh at one week after birth if it were not for the retardation of growth and loss of weight due to birth. In this way, we find that at one week after birth South Australian males should weigh 133.1 ounces. They actually do weigh, 121.4 ounces as we have seen. The *actual* loss due to the nutritional and mechanical shock of birth is therefore 11.7 ounces or 9.2 per cent. of the weight at birth.

The formula which similarly represents the growth of South Australian female infants is:

$$\log \frac{x}{350 - x} = 0.111\ (t - 2.47)$$

and from it we find that at one week after birth South Australian females should weigh 126.2 ounces. They actually do weigh 115.0 ounces. The *actual* loss due to birth is therefore 11.2 ounces, which is 9.2 per cent. of the weight at birth. Hence male and female infants suffer very nearly *equal* retardation of growth as a result of the nutritional and mechanical shock of birth.

Since heavy infants suffer a greater post-natal loss of weight than light infants and therefore tend to approximate them more closely in weight, we should expect the *variability* in weight of infants to *decrease* during the first week succeeding birth. This could only be the case, however, if the variability of the loss itself were equal to, less than, or not greatly in excess of the variability in weight of the infants, for otherwise a very highly variable effect of the shock of birth might conceivably lead to an *increase* in the variability of the infants.

As I have shown in the preceding section the variability of South Australian male infants at birth is 14.3 per cent. I find that the variability of South Australian male infants at one week after birth is 14.7 per cent. The variability of South Australian female infants at birth is 14.5 per cent. while at one week it is only 11.9 per cent.

It is evident that, in accordance with anticipation, the post-natal loss of weight is accompanied by a decrease in the variability of the weight of female infants. In male infants, however, a slight *increase* in variability accompanies the post-natal loss of weight. Evidently, therefore, the *variability* of *the effect of birth upon males is considerably greater than the variability of its effect upon females.* The greater variability of the effect of adverse influences upon male infants is in all probability correlated with the very much greater infantile mortality which prevails among males than among females,* since a greater variability of effect implies a more frequent overstepping of physiological limits.

During the *second* week of post-natal life there is a marked gain in weight, which not only makes good the loss of weight during the first week but considerably exceeds it. The average weight at two weeks after birth of all of the male infants (=203) born after periods of gestation lying between 245 and 325 days was 130.6 ounces; hence (of above) the average gain over the weight at birth at the end of two weeks of post-natal life is 3.3 ounces. The average weight at two weeks after birth of all of the female infants (=233) born after periods of gestation lying between 235 and 325 days was 124.2 ounces, the average gain over the weight at birth being 3.1 ounces.

These gains, however, although they more than serve to make up the *observed* losses of weight due to birth, do not entirely compensate for the *actual* loss (*i.e.*, the observed loss plus the gain in weight which the infant would have displayed had it not been for the retardation due to growth). This may be shown by putting $t = 0.47$(=two weeks) in the above formulæ and computing with their aid the weights which the infants should display at two weeks after birth. In this way we find that at two weeks after birth, South Australian male infants *should* weigh 139.3 ounces, whereas they actually *do* weigh 130.6 ounces. Hence, the retardation of growth due to birth, after two weeks of extra-uterine growth, amounts to 8.7 ounces, or 6.8 per cent. of the weight at birth. Similarly, we find that at two weeks after birth South Australian female infants *should* weigh 131.2 ounces, whereas they actually *do* weigh 124.2 ounces. Hence the retardation of growth due to birth after two weeks of extra-uterine growth is 7.0 ounces or 5.8 per cent. of the weight at birth. Although the gain in weight during the second week of extra-uterine life in not sufficient to make up entirely the loss due to birth, it will be noted that it *partially* does so, for in male children the loss of weight due to birth is 11.7 ounces at one week and only 8.7 ounces at two weeks. In other words, the effect of birth does not result in a *permanent* subnormality in the weight of the infant, because the loss of weight is made up by a *compensatory overgrowth* (*i.e.*, growth in excess of the normal increment corresponding to the given age and period) which amounts to 3.0 ounces in male children during the second week. This compensatory overgrowth is even more pronounced in females, amounting to no less than 4.2 ounces during the second week of extra-uterine life. Evidently females recover more rapidly than males from the inhibitive effects of birth upon their growth, a fact which is doubtless correlated with the greater tolerance of adverse conditions and the lesser variability of the post-natal loss which female infants display.

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* According to the Commonwealth Statistician's Official Year Book for 1914, pp. 145 and 172, the ratio of the male to the female death rate in Australia for deaths occurring less than one week after birth is 139 to 100.

The compensatory acceleration of growth during the second week may be shown in another way. From Equation (10) it may readily be computed that between the end of the first and the end of the second weeks of extra-uterine life the increment of weight in males, should be 6.2 ounces if their growth proceeded at the normal velocity indicated by preceding and succeeding weights. The observed increment, however, is no less than 9.2 ounces. Similarly, the increment during the second week in females which should be 5.0 ounces, is actually 9.2 ounces. Evidently the rate of growth in males is accelerated 48 per cent. and that of females no less than 84 per cent.

By the end of the first month of extra-uterine life this compensatory process has entirely made good the loss of weight due to birth so that at one month the observed weight of male infants is "normal," that is to say, it lies exactly upon the continuous curved line which represents preceding and succeeding growth. In the case of South Australian female infants, there would even appear to be an over-compensation, since the observed mean weight at one month is decidedly "super-normal."

From these facts it would appear that the normal weight of a growing organism at any given age represents a true dynamic equilibrium, any disturbance of which is rectified by internal regulation, just as a gyroscope restores equilibrium to a mass which has been displaced from its "normal" position through the action of an external force. If the induced displacement be too great, the inertia of the gyroscope may be insufficient to restore the mass to its original position; so analogously we may infer that if the induced sub- or super-normality of the weight of an organism, induced by the action of an adverse environment, exceeds a certain "physiological limit," the internal regulatory processes may be impotent to retrieve the damage to the economy of the organism.

The analogy to the gyroscope or to a pendulum extends even further. We may very frequently observe that a marked deviation from the normal form of the growth-curve of an infant is followed, not merely by a single compensatory acceleration or retardation bringing the curve back to normal, but by over-compensation followed by recompensation. This action may be repeated several times so that the growth-curve displays a series of oscillations of diminishing amplitude which succeed and are a remote consequence of the initial disturbance. This tendency, which is very well displayed in the growth-curve depicted in Fig. 3, is exhibited in some measure in the majority of the growth curves of individual infants.*

This "internal regulation" of the process of tissue growth is also very well illustrated by the phenomena of tissue-regeneration, whether following a wound when the neighboring tissues are especially stimulated to growth or following a more generally dispersed loss of tissue-material as in the marked nitrogen-retention following the wasting of fever or of starvation. The remarkable acceleration of tissue-accretion which occurs when a full diet is restored after an organism has undergone partial starvation is very well illustrated by the following experiment: †

Eight young white mice, varying in age between 52 and 123 days, which had hitherto been permitted free access to food and water, were found to weigh an average of 19.0 grams. They were then deprived of food for 27 hours and of water for the last four hours of this period. When they were weighed again their average weight was found to be only 15.3 grams. The loss due to 27 hours of starvation was therefore 3.7 grams or 20 per cent. of their original weight. They were then given free access to rolled barley, dried bread, and water. One hour later they were weighed again, and it was found that one-fourth (25 per cent.) of the above loss had already been made good; this represents, doubtless, the weight of the contents of the alimentary canal after a full meal. After 21 hours, no less than 87 per cent. of the loss had been made good, the average weight being now 18.5 grams. Had this rate of increment been continued these mice, already two-thirds grown, would have doubled their weight in five or six days.

The phenomenon of internal compensation is, of course, in entire harmony with the view that the growth of an organism is regulated by and is the expression of a series of underlying chemical reactions which are of such a nature that they produce their own catalyzers.

The specific velocity of the reverse reaction (tissue-degradation) is of comparable magnitude with that of the forward reaction so that the relative constancy of the weight ultimately attained in any cycle is determined by the attainment of equality of velocity by the two opposing reactions. Removal of the products (*i.e.*, of tissue materials) favors the forward by retarding the reverse reaction, and so, *vice versa*, an over-accumulation of products tends automatically to restore normality by the acceleration of tissue-degradation which is its consequence.

The variability of the weight of South Australian male infants at two weeks of age is 14.0 per cent., while that of females is 14.3 per cent. Evidently the extent of the compensatory over-growth is just as variable in both sexes as is the weight at birth, *i.e.*, as the preceding "normal" growth. Hence the diminished variability of female infants, which results from the post-natal loss of weight during the first week, is lost during the succeeding week owing to the variability of the normal and compensatory increments during that period.

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* *Cf.*, for example, the various growth-curves reproduced by Budin.[16]

† *Cf.* also, Schapiro (119) and Osborne and Mendel.[95]

The Second, or Juvenile, and Third or Adolescent Growth Cycles

Time-relations.—Data concerning the earlier portions of the Juvenile growth-cycle (second to ninth year inclusive) are, extremely scanty, since it is precisely from the second to the sixth years that human material becomes most inaccessible to systematic observation. For this reason, we are very seriously hampered in the quantitative evaluation of the parameters which would define the curves of autocatalysis representing the Juvenile and Adolescent cycles and are compelled to resort to more or less inaccurate approximations.[112] These two cycles, furthermore, are far less sharply demarcated from one another than the Infantile and Juvenile cycles. Their extremities fuse to some extent, so that growth during the 8th, 9th, 10th and 11th years, at least, is in part attributable to the latter portions of the Juvenile cycle and in part to the earlier portions of the Adolescent. Hence, although growth at this period is appreciably slower than it is during the preceding and immediately succeeding years, no pronounced "plateau" in the growth-curve is observed which is at all comparable with that occurring towards the end of the first year of extra-uterine development. Under these circumstances, the calculation of the parameters of the autocatalytic curves, which would quantitatively define the extent of growth at any given period, is attended by mathematical difficulties which it would be unprofitable to discuss in the present connection.

A great variety and abundance of data relative to the growth of children from school age onward, have been collected and statistically summarized in every civilized country. In England and America unfortunately, the figures thus accumulated and recorded include, as a rule, the weight of the clothing—a factor of very uncertain magnitude which must undoubtedly vary with age, sex, the economic status of the parents, and the climatic conditions under which the measurements were made. Under present conditions, however, it is difficult to see how in English speaking countries any very extensive data can be collected which are not subject to this disqualification. Schmidt-Monnard[145] allows from 6 to 8 per cent. of the observed weights for the clothing, while, in America, Bowditch considers that the clothing constitutes 8 per cent. of the observed weights.

The following are representative Anglo-American data.[3, 24, 14, 106]

TABLE 33.—GROWTH OF BRITISH AND AMERICAN CHILDREN

Age Last Birthday	American				British			
	Holt (New York) and Bowditch (Massachusetts)		Porter (St. Louis)		Anthropometric committee		Board of Health	
	Males	Females	Males	Females	Males	Females	Males	Females
	Pounds Avoirdupois		Pounds Avoirdupois		Pounds Avoirdupois		Pounds Avoirdupois	
2	27.0	26.0						
3	32.0	31.0	.....	.....	34.0	31.6	32.9	31.7
4	36.0	35.0	.....	.....	37.3	36.1	35.8	35.0
5	41.2	39.8	.....	.....	39.9	39.2	38.7	37.7
6	45.1	43.8	43.2	41.3	44.4	41.7	42.2	41.2
7	49.5	48.0	47.7	45.8	49.7	47.5	46.4	44.9
8	54.5	52.9	52.6	50.0	54.9	52.1	52.0	49.6
9	60.0	57.5	57.4	55.1	60.4	55.5	55.9	54.1
10	66.6	64.1	62.7	60.3	67.5	62.0	60.4	58.7
11	72.4	70.3	68.8	65.8	72.0	68.1	66.4	65.5
12	79.8	81.4	73.6	73.0	76.7	76.4	72.7	73.9
13	88.3	91.2	79.1	84.2	82.6	87.2	77.4	80.4
14	99.3	100.3	88.7	94.9	92.0	96.7	84.0	88.1
15	110.8	108.4	103.9	103.2	102.7	106.3	94.1	96.2
16	123.7	113.0	114.6	110.1	119.0	113.1		
17	....	.....	.....	.....	130.9	115.5		
18	.....	.....	.....	.....	137.4	121.1		
19	.....	.....	.....	.....	139.6	123.8		
20	.....	.....	.....	.....	143.3	123.4		

The difference between the averages given by Bowditch and those computed by Porter is probably to be sought in the differences of racial stock from which the children sprang. That between the British Anthropometric Committee's Report and the Report of the Board of Health is to be sought in the fact that the Anthropometric Committee obtained a large proportion of its data from measurements of children of the professional or relatively well-to-do classes while the Board of Health's figures refer to the scholars attending the board-schools, etc., *i.e.*, children of the relatively poorer classes.

The following are representative data from other countries: [64, 101, 154, 13, 76]

TABLE 34.—GROWTH OF CHILDREN OF VARIOUS RACES

Age last birthday	Swedish (Key)		Italian (Pagliani; Turin)		French (Paris) (Variot & Chaumet)		Philippino (Bobbit)		Japanese (Miwa)	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
	Pounds Avoirdupois		Pounds Avoirdupois		Pounds Avoirdupois		Pounds Avoirdupois		Pounds Avoirdupois	
1	.....	.....	.....	.....	20.8	20.5	.....	....	.....	.....
2	.....	.....	.....	.....	25.8	25.1	.....	....	.....	.....
3	.....	.....	27.4	24.6	28.9	27.6	.....	....	30.8	29.5
4	.....	.....	29.7	28.9	31.5	30.6	.....	.....	33.0	31.7
5	.....	.....	33.4	33.1	35.1	33.4	39.6	....	36.1	34.4
6	45.2	.....	36.8	36.2	38.6	38.3	41.4	41.8	37.8	37.0
7	50.2	47.5	42.6	38.8	41.8	41.8	44.6	44.6	41.8	39.4
8	57.8	55.1	45.7	41.7	46.6	46.8	47.0	50.3	44.6	43.1
9	64.6	59.3	49.4	48.4	52.4	52.6	50.8	51.2	49.3	48.0
10	66.7	64.8	54.7	54.3	56.2	58.3	57.0	56.5	51.8	52.5
11	71.0	70.3	58.6	59.4	61.2	63.8	62.4	65.6	57.0	57.8
12	76.0	79.0	64.5	65.0	66.3	74.6	68.5	73.8	62.1	66.0
13	83.0	87.0	72.6	76.0	78.7	84.2	77.2	80.3	72.6	73.3
14	93.2	98.6	80.5	84.8	92.2	95.0	91.3	88.1	83.3	85.8
15	103.0	107.8	92.2	96.7	102.3	101.6	100.0	91.5	92.8	91.0
16	115.5	113.7	102.0	100.8	.....	.....	103.6	95.5	100.3	93.8
17	126.3	120.2	115.9	104.5	.....	.....	107.8	97.0	109.6	99.3
18	135.0	124.1	118.8	107.0	.....	.....	111.4	94.0	108.2	108.6
19	139.6	126.3	121.3	.....	.....	.....	112.0	93.6	112.0	99.5
20	144.0	127.0	......	.....	.....	.....	111.6	....	111.8	101.6

It will be observed that in every race there is a brief period slightly antedating puberty during which the average weight of girls exceeds that of boys.[14] The explanation of this phenomenon lies in the fact that although the absolute magnitude of the adolescent growth-cycle (= *A*) is less in females than in males, the center, or period of maximum growth-velocity of the cycle, occurs sooner in girls than in boys.[112] The result is that while boys are still growing relatively slowly, pausing before entry upon the rapid growth which is characteristic of the adolescent period, girls have already embarked upon it and temporarily outstrip their brothers in weight, attaining sexual maturity somewhat earlier. The adolescent growth of males, however, is more extensive in magnitude than that of females, so that soon after the adolescent growth-cycle begins males catch up with females and outstrip them in weight. Hence, the growth-curves of human males and females, in striking contrast to those of the animals hitherto most extensively studied,[34, 120] intersect one another at two points.

The following are representative estimates of stature:

TABLE 35.—STATURE OF BRITISH AND AMERICAN CHILDREN

Age last birthday	American		British			
	Holt (New York & Bowditch (Massachusetts)		Anthropometric Committee		Board of Health	
	Males	Females	Males	Females	Males	Females
	Inches		Inches		Inches	
2	32.5	32.5	33.7	32.3		
3	35.0	35.0	36.8	36.2	36.5	36.0
4	38.0	38.0	38.5	38.3	38.6	38.4
5	41.7	41.4	41.0	40.6	40.7	40.4
6	44.1	43.6	44.0	42.9	42.8	42.5
7	46.2	45.9	46.0	44.5	45.0	44.8
8	48.2	48.0	47.1	46.6	47.4	46.9
9	50.1	49.6	49.7	48.7	49.2	48.7
10	52.2	51.8	51.8	51.1	50.8	50.6
11	54.0	53.8	53.5	53.1	53.0	53.0
12	55.8	57.1	55.0	55.7	54.9	55.5
13	58.2	58.7	56.9	57.8	56.1	56.8
14	61.0	60.3	59.3	59.8	58.2	58.9
15	63.0	61.4	62.2	60.9	60.7	60.3
16	65.6	61.7	64.3	61.8		
17	....	....	66.2	62.5		
18	....	....	67.0	62.4		
19	....	....	67.3	62.8		
20	....	....	67.5	63.0		

TABLE 36.—STATURE OF CHILDREN OF VARIOUS RACES

Age last birth-day	Swedish (Key)		Italian (Pagliani, Turin)		French (Paris; Variot & Chaumet)		Philippino (Bobbit)		Japanese (Hashiga)	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
	Inches		Inches		Inches		Inches		Inches	
1	....	....	....	....	29.2	28.9				
2	....	....	....	....	32.5	32.1				
3	....	....	33.8	33.3	35.1	34.8				
4	....	....	36.1	35.8	38.2	37.7				
5	....	....	38.2	38.9	40.6	40.0				
6	45.6	44.4	40.6	40.1	43.2	42.8	43.1	....	41.2	41.1
7	47.6	45.6	44.4	42.8	45.1	44.7	44.6	45.1	44.4	41.3
8	49.5	48.4	46.6	45.4	47.0	47.0	46.0	46.2	44.6	43.8
9	51.5	50.0	48.7	47.5	49.2	49.1	47.6	48.4	46.0	46.2
10	52.3	51.8	49.9	50.0	51.1	51.0	49.1	50.0	47.2	47.2
11	53.4	53.8	50.8	51.8	52.4	52.9	51.1	51.4	49.1	49.0
12	55.1	56.2	52.5	53.8	54.1	55.8	53.5	54.4	50.0	51.0
13	56.8	58.2	54.6	56.0	57.0	57.5	55.3	56.1	51.8	52.3
14	58.5	60.0	57.2	58.8	60.5	60.0	57.8	57.2	53.0	54.0
15	61.3	61.8	59.7	60.0	62.8	60.8	60.6	58.1		
16	63.6	62.5	62.0	60.6	....	....	62.3	58.5		
17	65.6	62.8	62.8	61.2	....	....	63.1	59.0		
18	66.8	62.8	63.2	61.2	....	....	63.3	58.8		
19	67.2	63.7	63.6	....	....	....	63.6	58.9		
20	67.5	62.8	....	....	....	....	63.7	58.8		

The influence of environment upon the Juvenile and Adolescent growth-cycles, particularly upon the latter, is no less marked than that of sex and race. The British Anthropometric Committee exhibited this effect in a most striking manner, by classifying their data according to the source from which they were derived, namely, the professional, artisan, and laboring classes. The inferiority of the development of children of the last named class, particularly in the period of adolescence, was most decided; while the figures of the artisan class came in between the professional and the laboring classes.*

Criteria of Normality.—As in the case of the infantile growth-cycle, individual deviations from the standard average weight or stature, when they are not too extreme, have little significance, except when viewed with reference to the whole growth-curve of the individual under consideration. The normal variability of weight in children of a given age is very great, varying from 11 to 20 per cent., while the variability of stature, which is considerably less than that of weight, varying from 4 to 6 per cent. is, nevertheless, sufficient to introduce a considerable margin of normal departure from the standard average.[11, 12, 14, 102, 151] On the whole, variability increases with increasing velocity of growth, *e.g*, at puberty, and decreases with decreasing velocity of growth, as, for example, in the adult.[102, 120, 126, 151]

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* *Cf.* also Hertz,[53] and Mackenzie and Foster.[75]

It would appear probable that a high degree of variability is a condition which is disadvantageous to the collective welfare of the individuals displaying it since a high frequency of marked departures from the mean implies a frequent overstepping of physiological limitations. Conversely, other conditions being equal, a disadvantageous environment might be expected to cause an increase in variability through enhancing preëxisting differences or at any rate preëxisting subnormality. It is to be borne in mind, however, that disadvantageous environmental conditions may cause a *retardation of the growth* of young animals or children, which in its turn, might be expected to lead to a *decrease* in variability as we have seen. Where the disadvantageous conditions operate at a period of rapid growth,

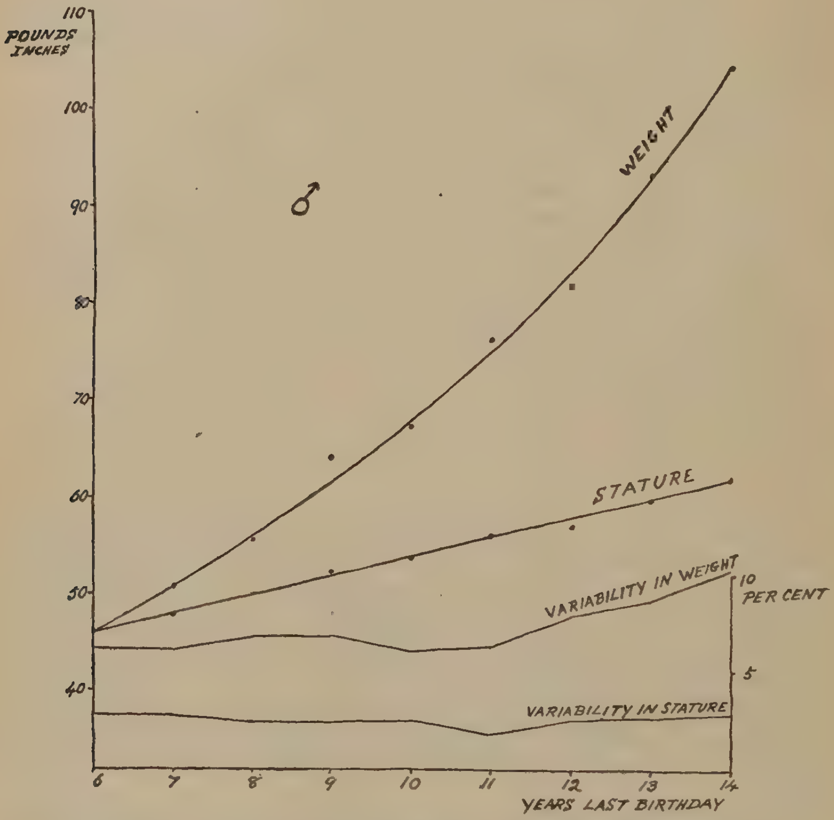

FIG. 193.—Variability of school-children in stature and weight (boys).

or growth of which the rate is fluctuating, the retardation of development due to an unfavorable environment would lead to important modifications of the dimensions of individuals, which in turn, might be expected to lead to a diminution or subnormality of variability; whereas the same conditions, pressing upon an adult animal or man or upon an animal or human being growing at a relatively slow or steady rate, might be expected to lead to an enhancement or supernormality of variability.

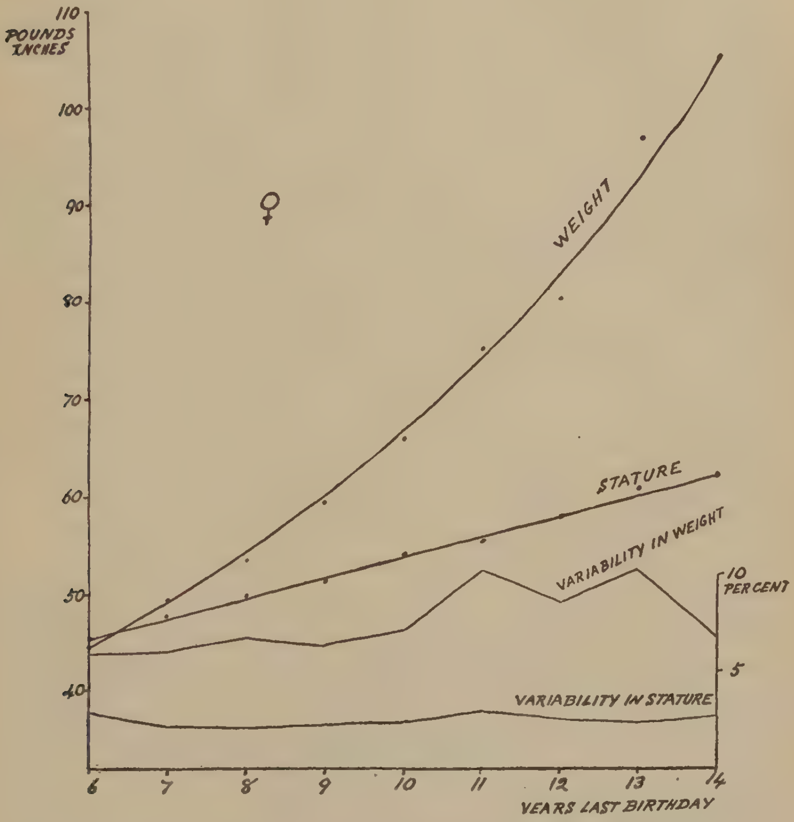

Fig. 194.—Variability of school-children in stature and weight (girls).

I have investigated the weight and stature and the variability of these dimensions in fifty children of each sex, from six to fourteen years inclusive, chosen from among children attending the schools in Oakland, California.[127] The results are indicated in the accompanying tables and displayed graphically in figures:

TABLE 37.—MALES

Age in years last birthday	Average weight in pounds	Yearly increment	Variability, per cent.	Average stature in inches	Yearly increment	Variability, per cent.
6	46.0	....	12.2	46.1	...	5.6
7	50.7	4.7	12.1	47.9	1.8	5.5
8	55.4	4.7	13.5	50.3	2.4	4.8
9	64.0	8.6	13.7	52.2	1.9	4.9
10	67.1	3.1	12.0	53.5	1.3	5.1
11	75.9	8.8	12.6	56.0	2.5	3.6
12	81.3	5.4	15.7	56.7	0.7	5.1
13	92.6	11.3	17.3	59.6	2.9	5.2
14	103.6	11.0	20.3	61.7	2.1	5.7

TABLE 38.—FEMALES

Age in years last birthday	Average weight in pounds	Yearly increment	Variability, per cent.	Average stature in inches	Yearly increment	Variability, per cent.
6	44.4	....	11.9	45.3	...	5.8
7	49.4	5.0	12.0	47.7	2.4	4.4
8	53.5	4.1	13.4	49.8	2.1	4.1
9	59.7	6.2	12.8	51.4	1.6	4.6
10	66.1	6.4	14.2	54.2	2.8	4.8
11	75.2	9.1	20.3	55.5	1.3	5.8
12	80.7	5.5	17.1	58.0	2.5	5.2
13	97.3	16.6	20.5	61.1	3.1	4.7
14	105.6	8.3	13.6	62.4	1.3	5.4

From these results, it is evident that the rate of growth in weight in both sexes increases continuously from the seventh to the fifteenth year and that the variability in weight undergoes a parallel increase during this period. There is a manifest tendency for maxima of variability in weight to coincide with maxima of yearly increment. The stature, on the other hand, increases during this period at an almost uniform rate, and the variability of stature is correspondingly uniform.

In satisfactory accord with the results cited above, the variability in stature is much less than the variability in weight. We may therefore infer that as a criterion of abnormality in children of these ages the measure of stature is more reliable than that of weight, for a given departure from the standard average has a proportionately greater significance than a like departure from the standard average of weight. On the other hand, as a sensitive *indicator* of the effects of environmental or dietetic fluctuation, the measure of weight is to be preferred to that of stature, since it is evidently more sensitive to internal and environmental departures from the average and more susceptible to modification. In investigations of child-welfare, as evidenced by growth, we may therefore be guided by the following practical rule: When we wish to compare the condition of two given groups of children in regard to physical welfare, we should preferably compare their average *statures* and the variabilities thereof; whereas, when we wish to compare the effects of differing diets or environmental conditions upon otherwise similar children, we should preferably compare their average *weights* and the variabilites thereof. In other words, when our object is the comparison of *children* we should use the height-standard, but when our object is the comparision of *environments* we should use the weight-standard of comparison.

In order to estimate directly the influence of environment upon variability of weight and stature, I took for the purpose of comparison, three groups of children fifty to a group, equally divided between the sexes, all of them eight years of age. The first group was chosen at random from the records of a school situated in a relatively poor industrial district of Oakland inhabited mainly by factory operatives; the second, similarly chosen from a school situated in a relatively wealthy residential district; and the third from an average school. The results of this comparison are summarized in Tables 39 and 40, which include, for the purpose of showing the degree of medical care received by the children of these three classes, the percentage of cases of infected or operated adenoids.*

TABLE 39.—MALES

School	Average weight in pounds	Variability, per cent.	Average stature in inches	Variability, per cent.	Percentage of children having	
					Infected adenoids	Adenoids removed
Residential district....	59.6	14.2	50.8	4.2	10	34
Average district.......	55.4	13.5	50.3	4.8	16	6
Factory district.......	55.3	10.3	48.3	5.1	24	2

TABLE 40.—FEMALES

School	Average weight in pounds	Variability, per cent.	Average stature in inches	Variability, per cent.	Percentage of children having	
					Infected adenoids	Adenoids removed
Residential district....	58.0	12.1	50.8	4.1	0	12
Average district.......	53.5	13.4	49.8	4.1	14	2
Factory district.......	51.7	11.7	48.5	4.5	10	2

---

* The parents of the children attending the school situated in the industrial district included a large proportion of individuals of foreign birth. It is not believed, however, that this factor invalidates the conclusions drawn from

From these results it is evident that, as previously found in England and Denmark,[3, 53] increasing unfavorability of environment results in a parallel increase of deficiency in weight and stature. It is a strikingly significant fact, also, that as the environment grows unfavorable, the proportion of medical care extended to children decreases as indicated by the percentage of adenoid pathology.

The variability of weight, which is normally high, decreases in an unfavorable environment in consequence, as explained above, of the retardation of the rate of growth in weight which is also an effect of such an environment. The variability of stature, which is normally much less pronounced, *increases* in consequence of the enhancement of normal deviations from the average, which in this case more than compensates for the reduction of variability due to slackening of growth. We may infer then, that among children of this age *a defect in stature and weight, with a high variability of stature and low variability of weight, is indicative of the operation of an unfavorable environment.*

A criterion of normality which has been suggested by von Pirquet, consists of the ratio of ten times the weight in kilograms to the cube of the sitting height in centimeters.[11] This index he calls the "Pelidisi." There is, however, no reason for preferring an arbitrary index of this character to the ordinary measurement of height, unless it can be shown, by the statistical methods outlined above, that the "Pelidisi" is actually less variable than the stature, in which case, of course, departures from normality would be possessed of correspondingly greater significance. The measurement of sitting height is, moreover, complicated by certain sources of inaccuracy* which are absent or minimized in the measurement of height (Martin, p. 138). It is necessary, also, to recall the fact that any standard of height, weight, or proportion of these to one another which is applicable to one race, or in one country, is not applicable to another race, or even

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the above comparison, for, on the one hand, there is no reason to suppose that the children attending the other schools were less heterogeneous racially than the children attending the school in the industrial district. They represent in the majority of cases the offspring of persons whose parents were themselves of non-American nativity. On the other hand, while racial heterogeneity in the absence of other factors might be expected to enhance the variability of *every* characteristic and dimension, the children from the industrial district were actually *less* variable in weight, although more variable in stature, than those from the average and residential districts.

* These sources of error are the following: 1. It is harder, especially in the case of children, to straighten the back when sitting than when standing. 2. The sitting height varies considerably with the position of the legs. The thighs should be horizontal and parallel and the feet flat upon the ground. This involves, in measuring the sitting height of children, the employment of a chair of adjustable height. 3. The measurement is much influenced by the degree of development of the gulteal muscles and fat deposits, and their compression due to the weight of the subject, while standing height is little affected by the comparatively invariable thickness of the soles of the feet. 4. Inclination of the head introduces a greater proportional error into the measurement of sitting height than it does into the measurement of standing height.

to the same race inhabiting another country, without a fresh estimate in each instance, of the magnitude of the standard norm.

CHANGES IN BODILY PROPORTIONS AND STRUCTURE WHICH ACCOMPANY GROWTH

Were the growth of an organism expressed by a single autocatalytic curve, we should expect the bodily proportions to remain essentially unaltered throughout development. The uniformity and simplicity of the process and the character of the quantitative relations defining it would imply uniformity in the composition of the products of the underlying and determining chemical reactions and consequently, uniformity in the composition and morphological type of the tissues produced. However, as we have seen, the total growth of an animal or of a human being is the sum of at least three distinguishable autocatalytic processes, each of which, we may safely infer, produces a distinctive type of product differing from that produced by other cycles. Hence, the growth of the various tissue-elements is unequally favored in the different cycles with the result that the relative proportion of the structures embodying these tissue-elements alters considerably as development progresses. In conformity with this conception, we find that the alteration of bodily proportion which normally accompanies development, is dependent upon the actual occurrence of growth and not upon the *age* of the animals Rats, which have been

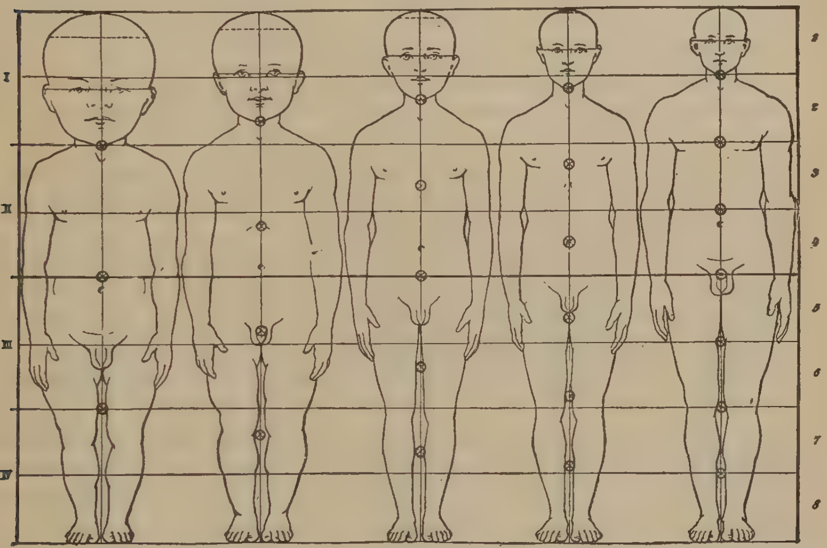

FIG. 195.—Changes in bodily proportion with growth, showing the length of different portions of the body as compared with the head at different periods of life. At birth the body is 4 heads high, while in the adult it is 8 heads high. (After Stratz, Der Körper des Kindes, 1904, 64, Fig. 42.)

stunted by underfeeding or the lack of a dietary constituent essential for tissue-synthesis, retain infantile bodily proportions to an advanced age.[94, 61, 5]

The alterations in the proportional growth of the several tissues which accompany development lead to manifest changes in external bodily proportions. These changes which are illustrated in the following schematic diagram[149] are primarily evidenced by a notable decrease in the relative magnitude of the head in proportion to the trunk and a relative lengthening of the extremities, particularly of the legs.

Accompanying these alterations in external proportions, consequent upon growth, are alternations resulting, on the whole, in a decrease of *bodily density*. The bodily density may be estimated, either by computing the percentage ratio of the cube-root of the weight to the stature, which yields the so-called "ponderal index"[68] or, more conveniently, by computing the percentage ratio of the weight to the cube of the stature.[139] Whichever method of computation be employed, it is found that the bodily density attains a maximum at the conclusion of the first year of extra-uterine life (end of the first cycle) and thereafter sinks, at first rapidly and then gradually, until the initiation of the third growth cycle (11 years of age in males, 10 years of age in females), when it undergoes a slight but continuous increase which persists throughout life (Martin, p. 246). We may, therefore, infer that the first and third cycles of growth are accompanied by a more or less pronounced *increase* in bodily density, while the second or Juvenile cycle is characterized by a *decrease*.

The ratio of bodily *surface* to weight or stature presumably undergoes similar alterations with development. The computation of the superficial area of the body from the more readily measurable dimensions has frequently been attempted in consequence of the importance of a measurement of superficial area in relation to the calorific requirements of the individual. The formula usually employed is that of Meeh[84] which, however, yields trustworthy results only for adults of approximately normal form, the results for obese individuals being high and for lean individuals correspondingly low.[38] The formula proposed by D. and E. F. Dubois is the following:

Surface of Head = $A \times B \times 0.308$
A = Circumference around vertex and chin.
B = Circumference around occiput and forehead, just above eyebrows.
Surface of Arms = $F(G + H + I) \times 0.558$
F = Outer end of clavicle to lower border of radius.
G = Circumference of arm at the level of the upper border of the axilla.
H = Largest circumference of forearm.
I = Smallest circumference of wrist.
Surface of Hands = $J \times K \times 2.22$

J = Lower posterior border of radius to tip of second finger.
K = Circumference of open hand at knuckles.
Surface of Trunk = $L\ (M + N) \times 0.703$
L = Suprasternal notch to upper border of pubes.
M = Circumference of abdomen at level of umbilicus.
N = Circumference of thorax at level of nipples in the male and just above the breasts in the female.
Surface of Thighs = $O\ (P + Q) \times 0.508$
O = Superior border of great trochanter to lower border of patella.
P = Circumference of thigh just below level of perineum.
Q = Circumference of hip and buttocks at level of trochanters.
Surface of Legs = $R \times S \times 1.40$
R = Sole of foot to lower border of patella.
S = Circumference at level of lower border of patella.
Surface of Feet = $T(U + V) \times 1.04$
T = length of foot.
U = Circumference of foot at base of little toe.
V = Smallest circumference of ankle.

The internal modifications of bodily proportion which accompany growth are summarized by Thompson[151] in the accompanying table.

The progressive modifications in the proportional development of the various tissue-elements which accompany the growth of children necessarily involve manifold structural modifications which cannot be discussed in detail here.* The modifications which are of primary significance to the pediatrician are, however, those which lead to the erruption of teeth, the closure of the fontanel, and the growth and degeneration of the thymus.

According to Holt and Howland,[55] the following are the approximate dates of eruption of the milk teeth, subject to wide individual variation:

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* The changes in the chemical composition of the body which necessarily accompany these changes in the proportionate development of different tissues are as yet very imperfectly known. The most striking effects appear to consist in a progressive desiccation (E. Bischoff,[10] and a marked diminution of the phospholipin content of tissues other than those of the central nervous system. (T. Brailsford Robertson;[120] D. I. Sivertzov;[146] *cf.* also L. B. Mendell, and collaborators.[86]

Table 41.—Percentage of Weights of Various Organs as Compared with Body Weight

Age in years	Body	Brain	Heart	Liver
0	100	12.29	0.76	4.57
1	100	10.50	0.46	3.70
2	100	9.32	0.47	3.89
3	100	8.86	0.52	3.88
4	100	9.50	0.53	4.20
5	100	7.94	0.51	3.39
6	100	7.63	0.48	3.45
7	100	6.84	0.47	3.49
8	100	6.38	0.44	3.01
9	100	6.06	0.46	2.99
10	100	5.59	0.51	3.32
11	100	5.04	0.52	3.22
12	100	4.88	....	3.03
13	100	4.49	0.50	3.13
14	100	3.47	0.58	3.20
15	100	3.62	0.48	3.17
16	100	3.16	0.51	2.95
17	100	2.84	0.51	2.98
18	100	2.64	0.46	2.80
19	100	2.43	0.51	2.86
20	100	2.43	0.51	2.62
21	100	2.31	0.49	2.66
22	100	2.14	0.50	2.66
25	100	2.16	0.46	2.75

Table 42.—Eruption of Milk Teeth

2 Lower central incisors	6 to 9 months
4 Upper incisors	8 to 12 months
2 Lower lateral incisors and 4 Anterior molars	12 to 15 months
4 Canines	18 to 24 months
4 Posterior molars	24 to 30 months
At 1 year a child should have	6 teeth
At 1½ years a child should have	12 teeth
At 2 years a child should have	16 teeth
At 2½ years a child should have	20 teeth

The permanent teeth appear in the following order:

Table 43.—Eruption of Permanent Teeth

First Permanent Molars	6 years
Incisors	7 to 8 years
Bicuspids	9 to 10 years
Canines	12 to 14 years
Second molars	12 to 15 years
Third molars	17 to 25 years

Delayed dentition is a characteristic sign of rachitis.

The posterior fontanel usually is closed by the end of the second month; the sutures of the skull are immobilized by the sixth month; and the anterior fontanel closes at about the eighteenth month, the time of closure varying between 14 and 22 months. An open fontanel in a normal non-rachitic child at the end of the second year is very unusual.

A striking characteristic of the third growth-cycle is the rapid degeneration of the thymus. According to Friedleben,[30] the average weight of the thymus at birth is 13.7 grams; from birth to 9 months, 19.8 grams; from 9 months to two years, 26.2 grams; and from the third to the fourteenth year, 25.9 grams. Holt and Howland consider that these weights are excessive and cite with approval the estimates of Bovaid and Nicoll, namely 6.5 grams at birth, 4 grams during infancy and early childhood. The estimates of Friedleben, however, are confirmed by those of Hammar[50] who states that the normal weight of the thymus in man at various ages is as follows:

MONTHS	GRAMS
At birth	13.3
Between 1 and 5	23.0
Between 6 and 10	26.1
Between 11 and 15	37.5
Between 16 and 20	25.6
Between 56 and 65	16.1
Between 66 and 75	6.0

Retrogressive changes are already beginning, however, in the second year. In the years subsequent to adolescence the adenoid tissue of the thymus has, in normal individuals, been largely replaced by adipose tissue. Evidently the thymus bears a special relationship to the first growth-cycle, increasing continuously in weight during its duration, remaining stationary during the second growth-cycle, and degenerating rapidly during the adolescent cycle, so that when adult state is reached, a functional gland is usually absent. Occasionally we find children in whom the birth-weight of the thymus is much greater than that cited above. Such children usually display lymphism and a marked tendency to sudden decrease after some trivial shock, the causation of death being as yet quite obscure.[55]

PERIODS OF INSTABILITY IN THE GROWTH-PROCESS

It has been shown by Read[110] that there is a definite "critical period" in the intra-uterine development of the guinea-pig, somewhat ante-dating normal delivery, at which premature delivery of young, which are usually born dead, is more likely to occur than at any other. This "critical period" corresponds with the conclusion of the first growth-cycle, which, is completed *in utero* in the guinea-pig. It would appear, therefore, that in this animal the juncture of the first and second growth-cycles constitutes a period of relative instability in the growth-process, due possibly to the faulty "linking-up" of the two growth-cycles. In man this juncture of cycles occurs in the latter part of the first year of extra-uterine growth. The question therefore arises, whether or not at this age, a similar relative instability is displayed by human beings.

That the latter half of the first year of extra-uterine growth is in reality a "critical period" in the development of man is shown by the investigations of Macgregor,[73] who has determined the relationship of weight to age in over 1700 infants admitted to the city of Glasgow Fever Hospital during the years 1907–1908. Macgregor finds that for children under one year of age, the weight on admission increases fairly uniformly from 3 to 6 months and is tolerably close to the average for Glasgow children of the same age. After 6 months, however, the curve of growth has its continuity suddenly broken, descending to a relatively low level, and only regaining its natural position as the end of the first year is reached. Evidently, children who fall victims to zymotic disease during the second half of the first year of extra-uterine life, tend to be of markedly subnormal weight before any loss of weight due to the disease, itself, has occurred. Moreover, the incidence of measles, whooping-cough, and scarlet fever reaches a maximum at the eighth and ninth months, while diphtheria and cerebro-spinal meningitis, although occurring rarely during the first year show a maximum incidence during the sixth and seventh month. From these facts it appears, *firstly*, that there is a tendency for a certain proportion of infants to be of markedly subnormal weight between the seventh and the tenth months, and *secondly*, that these subnormally developed infants are selectively affected by certain zymotic diseases. On comparing Macgregor's growth-curve of infants under one year of age who have contracted zymotic disease with Read's growth-curve of prematurely delivered guinea-pigs, it is impossible not to be struck by their remarkable similarity.

It might be imagined that the tendency of a proportion of infants to exhibit underweight at from seven to ten months is attributable solely to the fact that weaning "normally" (*i.e.*, physiologically) should take place at this period, that the digestive disturbances frequently consequent upon this change of diet affect a certain proportion of children more severely than others, and that these children are selectively affected by zymotic diseases. These considerations, however, do not suffice by themselves to explain the phenomena observed by Macgregor for in the first place, as he points out, bottle-fed infants supplied with milk from the city milk-depots of Glasgow show no loss of weight during the seventh to tenth months at all comparable with the subnormality exhibited by the infants admitted to the Fever Hospital. Bottle-feeding, therefore, does not affect average infants more adversely during the seventh to tenth months than at any other period. Now, under the conditions pertaining in a modern city the weaning of infants is by no means usually delayed until the "physiological" period. From the data collected in Birmingham by H. W.

Pooler[105] it appears that not over two-thirds of the children of poor parents are breast-fed. This percentage is still smaller among children of wealthier parents. Among those infants who are breast-fed, weaning occurs at a very great variety of ages owing to digestive disturbances. Infants of subnormal weight should therefore be distributed fairly evenly among all ages during the first year, unless bottle-feeding tends to have a more deleterious effect upon infants of between seven and ten months of age than at other ages, which, as we have seen, is not the case.

It may be pointed out, also, that it is undoubtedly by no means accidental that the "physiological age" for weaning approximately coincides with the termination of the infantile and the inception of the juvenile growth-cycle. It is, indeed, highly probable that a change from one growth-cycle to a succeeding cycle involves profound changes in the metabolism of the organism, so that pronounced changes in physiological habit or mode of development might be expected to occur at such periods coincidently with the deeper-seated metabolic changes.

It would be of very great interest and importance to determine whether or not there is a similar period of relative instability of the growth-process at the juncture of the Juvenile and Adolescent cycles, and also whether specified infections, abnormalities of development, etc. exhibit preference for the one or the other period of instability. Reliable data bearing upon this problem are, so far as I am aware, scanty or altogether lacking.

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CHAPTER V

PHYSIOLOGY OF METABOLISM IN INFANCY AND CHILDHOOD

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INTRODUCTION—DISTINCTION BETWEEN SUBSTANCE AND ENERGY

Metabolism, as the term is now generally understood, includes all the chemical and physical processes by which the living substance in organized form is produced and maintained, as well as the transformations by which energy is made available for the various purposes to which it is put in the organism. It is important at the beginning of a discussion of these fundamental matters to have in mind a clear distinction between substance metabolism and energy metabolism.

The two sets of processes denoted by these terms are by no means entirely independent of each other, although they probably rest upon fundamental properties of the living substance which are quite distinct.[158] These properties, as nearly as they can be denominated at present, are, on the one hand, the ability to attract and impress into its own structure germane materials, and, on the other, the ability to liberate, in most cases by oxidation, the energy supplied to it in potential form. Because one is at bottom synthetic in nature and the other analytic, the two properties have frequently been regarded as direct opposites, and the terms anabolism and katabolism have served to emphasize this distinction. But these latter terms have led to some confusion. Introduced at a time when Liebig's view of the coincidence of substance and energy changes was the prevailing view, they have served through indiscriminate usage to prolong the life of an idea long past its usefulness. Liebig believed that whenever new protoplasm is formed energy is stored, and that the liberation of energy necessarily involves a destruction of protoplasm. But from our present knowledge of the constitution of the protein substrate of the living unit (or biophore, as it is sometimes called), it requires but a moment's reflection to convince one's self that the conversion of, say, casein of cow's milk to protoplasm of a baby's muscle, assuming that no reduction in the chemical sense is necessary to vitalize this protein, involves no storage of energy whatsoever; and it has been abundantly proved by the Voit school of investigators that the destruction of the living substance (as measured by output of nitrogen in the urine) is by no means proportional to its activity, *i.e.*, the amount of energy liberated.

A few citations should serve to make this matter entirely clear. Thus Lengyel[98] and Hari[59] made calorimetric studies upon the heats of combustion of proteins before and after digestion and found them essentially the same. Grafe[66] also attempted by means of an extremely sensitive calorimeter to detect a production of heat during proteolysis but without success. Cleavage of proteins into polypeptids (peptones) and amino-acids yields no energy. If our assumption is true that synthesis of proteins beyond the alimentary tract arises from these same cleavage products, and the better opinion of biochemists is to this effect, then their construction in the body cannot be accompanied by storage of energy in the sense in which this takes place when starch is synthesized, under the influence of the sun's rays, from carbon dioxide and water. Hence, the antithesis of constant building up and tearing down of the living substance as a condition of energy release, which the terms anabolism and katabolism have mistakenly been used to emphasize, is not true, although it is still taught in some quarters. Perhaps the best usage of these terms at present is limited to the action of the living substance upon lifeless material as when we speak of the anabolism of glycogen or the katobolism of glucose.

The dominating process of *substance metabolism* in the body of a growing child is the synthesis of proteins and their vitalization. Now synthesis of proteins is accomplished in the laboratory by union of amino-acids with elimination of a molecule of water in this fashion, and

$$\overset{\text{Alanin}}{NH_2.CH.CH_3.CO\ \ OH} + \overset{\text{Glycocoll}}{NH_2.CH_2.CO\ OH} =$$
$$\overset{\text{Alanylglycin}}{NH_2.CH.CH_3CO - NH.CH_2CO}\ \ \overset{\text{Water}}{OH + H_2O}$$

there is every reason to believe that this is the type process in the tissues.

The process is accomplished by a chemical change exactly comparable with that by which maltose is synthesized from two molecules of dextrose.

$$C_6H_{12}O_6 + C_2H_{12}O_6 = C_{12}H_{22}O_{11} + H_2O$$

There is no storage of energy because there is no change in the relation of carbon to oxygen, the hydrogen in both molecules being entirely satisfied.

Once formed, the living substance, so long as it is living and under the conditions usually termed normal, seems to be relatively stable, so far as oxidation is concerned, but it is endowed with the property of "activating" oxygen, and this enables it to bring about the oxidation of inert materials (fats, carbohydrates, and, after splitting off of the nitrogen, of nitrogenous materials as well) which may be brought into an intimate enough relationship with it. The growth or maintenance capacity of the living substance certainly is not the opposite of this, but is probably to be looked upon as a sort of polymerization, of a higher order than that just cited, whereby unitary components of the living substance attract similar unitary chemical structures which cannot themselves be described as living, but which take on the vital character in virtue of their incorporation into the more complex relationship. That the process of oxidation is a condition essential to the continuance of this polymerization is, perhaps, a safe inference from its almost universal association therewith (see page 552).

Since the chemical basis of the living substance is essentially protein in nature, the study of the substance metabolism resolves itself mainly into a study of the chemical changes in the protein materials entering the organism as food, from the moment their digestion begins until their reappearance in the external world as waste. The study of the energy metabolism, on the other hand, concerns itself mainly with the oxidation of non-nitrogenous materials.* One is obliged to say "mainly" in both cases, because, in the first place, certain cells always normally, and most cells at times, contain non-nitrogenous materials which fluctuate in amount with the nutritive condition of the living substance, and in this sense are to be regarded as part of it; and, in the second place, some energy probably always is derived from what were, before deamination, nitrogenous materials.

ENERGY METABOLISM

General Considerations of Energy Metabolism in Warm-blooded Animals

Heat Production.—It is a familiar experience that the temperature of what we call "warm-blooded" animals is not only several degrees higher than the average temperature of the atmosphere, but is held constantly at this level despite fluctuations in the environing temperature. Merely to warm the body once up to this level of 37 degrees from the temperature of the air (which the body would have, if dead) requires a considerable amount of heat.† To maintain it constantly requires much more, and requires very sensitive adjustment to different rates of heat loss.

Oxidation.—The heat all comes, in the last analysis, from the oxidation of food stuffs in the tissues. Oxygen is carried to the tissues by the blood—for the most part in combination with the hemoglobin of the red corpuscles. The food stuffs are likewise carried to the tissues by the blood, but in solution in the plasma. Under certain forms of stimulation, the cells receiving both oxygen and food activate the oxygen and cause it to unite with certain chemical groupings derived from the food, and the result is the liberation of energy which takes one of three forms: mechanical work, electrical currents, or heat.

By far the greater part of this energy takes the form of heat; for, at the best, *i.e.*, working under the most favorable conditions, the tissues are unable to convert more than one-third of the potential energy of the food into mechanical work; and, ordinarily, the amount so converted is not more than one-sixth. The amount taking the form of electrical energy is almost infinitesimally small.

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* Rubner,[158] p. 34: "Beim Eiweiss drängt sich in der Ernährung die substantielle Frage, beim Fett und Kohlehydrat die dynamogene in den Vordergrund."

† The specific heat of the human body being 0.83 (Pembrey), it may be calculated that an adult body weighing 70 kg. would be equivalent to 57.1 kg. of water, so that to warm it 1 degree would require 57.1 calories of heat. To warm it 20 degrees would require 1,142 calories or more than a third of the heat energy of the average daily intake of food.

Is Heat a By-product?—It is sometimes stated that the heat which results from oxidation in the animal body is simply a by-product of the internal work which takes place in the tissues. This can scarcely be a correct conception of the process of oxidation as a fundamental life-process, especially in warm-blooded animals; for the maintenance of a temperature well above that of the surrounding medium is an essential condition for the performance of the internal work (chemical reactions) in the tissues. It is fair to say, therefore, that the production of heat at a rate sufficient to offset the inevitable loss to its surroundings is a necessary function of every warm-blooded animal. The evolution of heat, however, is not confined to the higher animals but is common to all living beings. It is very evident, for example, in the germination of seeds, and in a hive of bees the temperature of the atmosphere is often 10 degrees above that of the surrounding atmosphere.

Van't Hoff's Law.—Increased activity in living tissues is almost invariably accompanied by an increased evolution of heat. Since this heat is derived from the chemical changes which proceed in the living cells, and since all chemical processes are quickened by a rise of temperature, we should expect to find that the heat produced in the metabolic processes of the organism would tend of itself to quicken these processes. This is found to be the case. In most chemical reactions a rise of 10°C. would increase the velocity of the reaction from two and a half to three times (Van't Hoff's Law), and the same law is, within the limits of the stability of living tissues, found to apply to the process of oxidation. For example, in the early growth of a lupine seedling it has been found that the output of CO_2 bears to the temperature the following relationship:

0°C.	6 mg. per hour
10°C.	18 mg. per hour
20°C.	44 mg. per hour
30°C.	86 mg. per hour

The same relationship has been found to obtain for the production of CO_2 in the snail, the leech, and the earthworm. Perhaps the absorption of oxygen is a still better measure of the heat production. Within the range of 5 to 21°C. it has been observed that the factor (Q_{10}), which, in biological literature, expresses the number of times the process is accelerated for a rise of 10 degrees, has, for the absorption of oxygen by the crayfish, a value of 2.5 to 3.5. In the case of the leech, the same factor, between 10 and 24 degrees, is from 2.4 to 3.0.

In living things the range within which any such law applies is necessarily very narrow as compared with its range in inorganic reactions; and the factor (Q_{10}) varies, according to the best determinations which have yet been made, very widely. Nevertheless, it may be said that the law that the rate of chemical change (metabolism) varies with the temperature of the living substance is a universal law for all animals and plants. As applied to the production of heat in living things, this law would result in a vicious circle (the temperature increasing the oxidation and the oxidation increasing the temperature) which would rapidly destroy the living substance itself, if special mechanisms did not exist for the removal of the heat. Where these mechanisms break down, as in fevers, the heat must be removed by artificial means.

Body Temperature.—We are not concerned in this chapter with body temperature as a symptom of disorder but only as a manifestation of oxidation and of its regulation in relation to heat loss. What is the actual temperature of the body? This much-mooted question cannot be settled even today, for the answer depends upon the place and means of its measurement. In general one may say that the farther interior the thermometer can be placed the higher is the temperature recorded; but some of the interior organs are warmer than others and this denotes that chemical activity is more vigorous there than elsewhere. Hence a safer statement is that the nearer the actual source of production the higher is the temperature. The nearer the surface the lower the temperature, particularly if the surface is unclothed and is the seat of evaporation of water.

Studies on the gradient in temperature from the naked surface of the adult body to the interior made by Benedict and Slack,[26] show that the rise from 32 degrees at the surface is very rapid for the first 5 cm. distance and then shows little change whether the test be made in the rectum or the vagina. It is safe to say, therefore, that a thermometer 6 or 7 cm. from the surface correctly records the temperature of the interior. This investigation proved also that a rise or fall in the temperature of the body in one part was in general accompanied by a parallel change in every other part. The temperature of clothed parts of the skin is naturally higher than that of the naked skin and may be estimated in general at from 33 to 35°C.

The organs of the abdominal cavity are warmer than the skeletal muscles or the rectum. According to Quincke[143] the temperature in the interior of the stomach of man is 0.12°C. higher than the rectal temperature, and, according to Ito,[88] that of the duodenum of the rabbit is 0.7°C. higher. These temperatures may be due to the proximity of the liver, for LeFevre[97] has found the liver of the dog more than one degree warmer than the rectum.

Individual variations of some tenths of a degree are always found when the temperature is recorded over sufficient length of time for each individual. As a mean value 37.5°C. is usually given for the temperature of the rectum, 37.2°C. for the axilla. It is not quite correct to say that these temperatures are constant; for, neglecting variations due to disease or to excessive cooling, it is well known that, in the course of the day, the body temperature undergoes certain normal variations. In a healthy individual the temperature difference between minimum and maximum in the diurnal curve may amount to 1 to 1.5°C. In ordinary habits of life the minimum comes between three and six o'clock in the morning and the maximum between five and eight o'clock in the evening.

Cause of the Diurnal Variations of Temperature.—The cause of these variations in the body temperature lies in the varying relations of heat production to heat loss. If heat production exceeds heat loss the temperature rises and *vice versa* where heat loss exceeds heat production the body temperature falls.

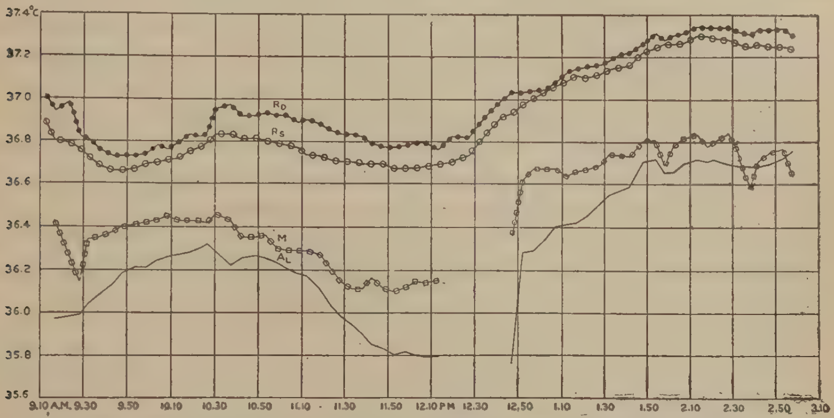

FIG. 196.—Temperature curves from Benedict and Slack showing parallel changes in body temperature, taken in mouth, axilla and rectum. Note low A.M. temperature and rise in afternoon; lunch was eaten 12:21 to 12:38 P.M. (Benedict and Slack, Carn. Inst. Publ. #155, Wash., D. C., 1911.)

The factors which, it is known, may be operative to affect the body temperature in this way are: muscular exercise, kind and amount of food, mental effort, light through its reflex effects, temperature of the surrounding medium, and sleep. Probably the first is the most important, but it requires the combined effect of all of them to account for the perfect regularity of the variations. Certain very careful observations by Mosso,[120] F. G. Benedict[10] and others indicate that there is a fixed periodicity in the body temperature which is entirely independent of any and all of these superficial circumstances. Benedict found that the minimum temperature in night workers persisted in falling in the early morning hours, "independent of whether the subject was sleeping soundly in the recumbent position or was awake and sitting or even standing and walking." Among the objections which have been brought against the work of Mosso and of Benedict on night workers is the fact that an individual worker cannot be entirely disconnected from the rest of society in this way. Thus, under a reversed day and night regimè, the subject necessarily works under artificial light in the stillness of the night, and he must sleep in the daytime through noise and other disturbing circumstance. "The nighttime has a peculiar effect upon the general state of one's mind owing to the solitariness and various other circumstances, and this changed psychical condition reacts on all one undertakes" (Lindhard). A less objectionable method of reversing the daily routine is that of taking a journey half-way round the globe. If the body temperature were subject to a rhythmical periodicity independent of the immediate surroundings, a journey of this kind from east to west or west to east would completely invert the day and night with reference to the local time from which one started, and should have the effect of replacing the minimum morning temperature by the maximum evening temperature, and *vice versa.* The first experiment of this kind was performed on himself by R. B. Gibson,[64] who made a journey from New Haven, Conn. to Manila, P. I. It has since been accomplished by Osborne[136] in a journey from Melbourne to London, and less completely, so far as extent of the inversion was concerned, by Simpson[183] in a journey from Ithaca, N. Y. to Edinburgh, Scotland. "Day" and "night" were reversed by Lindhard[99] in the polar night of N. E. Greenland in the following way. Observations were made on the body temperature of all of the twenty-eight members of the expedition during the "day," *i.e.*, the time during which the lamps were lighted and the men were active indoors, and again during the "night," *i.e.*, when the lights were put out and the men went to bed; also upon waking. Then by postponing the bed time four hours one day and eight hours the next day and the insertion of an extra meal the "day" and "night" were reversed. In all of these experiments the results were essentially the same. Complete reversal of the day and night produce a complete inversion of the diurnal temperature curve, showing that the curve is determined by work and the mode of living, and that "the astronomical division of time is without importance in this regard." Still more out of the question is any inherited form of the temperature curve or any mysterious "cosmic" influence.

Temporary changes of the body temperature in one direction or the other may be produced by various voluntary acts which tend to offset the heat production or the heat loss. Thus the temperature falls as the result of sitting perfectly still, of drinking cold water, eating ices, etc. It rises, as a rule, as the result of exercise, taking hot drinks or food, etc. However, all such variations are, as a rule, very insignificant, and this very remarkable fact has been established—that the mean value of the temperature obtained from a large number of determinations, extending over periods of 24 or 48 hours, remains the same in spite of all such disturbances. With a free choice of food, therefore, the body measures out its supply of energy to fit the circumstances of heat loss with unerring accuracy.

Variations of temperature between persons of different age are also but slight. The fetus, having a certain small metabolism of its own and being harbored among the warmest organs of the mother's body, might be expected to have a temperature slightly higher than the mother, which, indeed, direct observations confirm. The difference, however, amounts to only 0.3°C. Immediately after birth the temperature sinks sometimes as much as 2 to 4°C. and it may continue somewhat below normal until the end of the first week. This primary fall is not explained altogether by bathing for it has been observed in infants which were not bathed,[71] although the birth-bath may produce an even greater fall unless special means are taken to prevent it. The continued depression is explained in part by the time required for the process of adaptation to the new source of food. After its return to normal the temperature in health never varies far from this level. The following table after Benedict and Talbot[23] gives the average body temperature (rectum) taken at the beginning and end of a period of observation in their respiration chamber, for each of the first eight days of life.

TABLE 1.—AVERAGE RECTAL TEMPERATURE OF INFANTS DURING THE FIRST EIGHT DAYS AFTER BIRTH

Age	Number of subjects	Average temperature		Age	Number of subjects	Average temperature	
		Degrees Centigrade	Degrees Fahrenheit			Degrees Centigrade	Degrees Fahrenheit
1 to 12 hours	48	36.7	98.1	4 days	51	37.0	98.6
12 to 24 hours	26	36.9	98.4	5 days	41	36.9	98.5
1 day	74	36.8	98.2	6 days	22	37.0	98.6
2 days	65	37.1	98.8	7 days	16	36.9	98.5
3 days	62	37.2	99.0	8 days	9	37.1	98.8

The average for the entire 24 hours is lower than these figures. Jundell[192] gives the following as the average rectal temperatures for the 24 hours for persons of different ages:

Age	Degrees Centigrade
5 to 8 days	36.82
4 to 5 weeks	37.13
2 months	37.12
6 months	37.15
2 to 5 years	36.92
18 to 22 years	36.85

The variation for this range of ages amounts to only 0.33°C. For very old persons (71 to 98 years) the average rectal temperature, according to Chelmonski,[39] was 36.58°C. in the morning and 36.65° C. in the evening.

Subject to *excessive loss of heat* the body is unable to maintain the normal level of temperature and the disturbance to its functions is greater the lower the body temperature falls. The highest nerve centers are the first to suffer so that the person soon becomes unconscious. This fact explains the drowsiness of persons threatened with freezing from exposure. Life is maintained by the medullary centers, however, until reduction of the general body temperature has gone much farther. Theoretically, restoration is possible as long as these centers (respiratory center, vasomotor center, etc.) retain their vitality. Cases have been recorded of patients who have recovered from a body temperature of 22.5°C.,[89] and one case of a man who retained consciousness with a temperature of 26.7°C.

In like manner *an increase in body temperature*, if it passes a certain limit, involves first disturbances to the general health and later loss of consciousness, while the centers of the medulla remain functional. In general, it may be said that the body stands a fall better than a rise in temperature; for while, as seen above, it may recover from a fall of as much as 15°C., a rise of only 2 or 3°C. is a very serious matter, and a rise of 4 or 5°C., *i.e.*, to 41 or 42°C., constitutes a very dangerous symptom. Some of the highest authenticated temperatures[149] from which patients have recovered are: 43.6°C. in a case of syphilis of the brain (Paget); 42°C. typhoid fever (Thoma); 43.6°C. scarlet fever (Vincent and Bloch); 42°C. erysipelas (Hirz); 43.3° malaria (Mader); 43.9° acute rheumatism (Clinical Society of London).

After death the temperature of the body falls, but not always immediately. This shows that the heat production does not cease the moment the organism has taken its last breath. Besides, with the cessation of the circulation and the secretion of sweat any heat formed by the post-mortem phenomena in the interior of the body is not so readily lost. In cases of death from infectious diseases, the temperature of the cadaver may even rise for some hours after the usual signs of life have disappeared.

The Heat Producing Organs of the Body.—Heat is produced wherever oxidation takes place in the body. Every organ and tissue, therefore, must contribute its quota to the sum total. Some tissues, however, are in reality unimportant in this respect, notably the bones, exclusive of the marrow, the tendons, cartilage, the white matter of the nervous system and the skin. The organs and tissues which are known to be most active in the production of heat are: The cross-striated muscles, including the heart, the large glands (liver, intestine, stomach, spleen, pancreas, and kidneys), and the non-striated muscles. Taking the total heat production of a resting man of average weight (70 kg.) as 1,680 calories* (see below), Tigerstedt[192] has estimated that the contribution of the different organs is as follows:

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* A Calorie is the one-one-hundredth part of the heat necessary to raise 1 kg. of water from 0 degree (freezing) to 100 degrees (boiling) at sea level. It is quite customary in this country to use the amount of heat necessary to raise 1 kg. of water from 19 to 20°C., as one Calorie (written Cal. or Kilo-calorie). One-thousandth part of this is often called a small calorie, or a gram-calorie (written cal. or gm.-cal.).

Heart	70 Cal.
Muscles of respiration	150 Cal.
Liver	368 Cal.
Kidneys	74 Cal.
Skeletal muscles	1,000 Cal.
Total	1,662 Cal.

This leaves only a very small fraction of the whole to be produced by the less active organs.

That the skeletal muscles must be the most important seat of heat production follows from the fact that with every muscular contraction from three-fourths to two-thirds of the energy liberated is set free as heat (see below). It has been conclusively proved also that heat is constantly being produced even in resting muscles. Thus, Meade-Smith[112] determined the temperature of the vastus externus and profundus muscles of the dog simultaneously with the temperature of the blood in the aorta, with the following results:

Muscle	Blood	Difference
38.38°C.	37.97°C.	0.41°C.
38.41°C.	38.13°C.	0.28°C.
38.74°C.	38.21°C.	0.58°C.
38.28°C.	37.90°C.	0.38°C.

It may be calculated from his observations that nearly 10 calories of heat are produced in 1 kg. of resting muscle in 24 hours.

Proof of the Sources of Animal Heat (Calorimetry).—Proof that the ultimate source of the heat produced in the animal body lies in the oxidation of its organic foodstuffs dates from the time of Lavoisier, the discoverer of oxidation (1789). Lavoisier invented a calorimeter which measured the heat produced by a small animal in terms of the number of grams of ice melted. By means of another apparatus which was never described fully (the inventor's notes having been destroyed in the French Revolution, during which he was beheaded), Lavoisier learned not only that oxidation is the source of heat in the human body, but that the amount of heat so produced is greater during muscular work, after taking food, and greater at a low than at a high external temperature.

Lavoisier assumed that the heat value of a compound was equal to the sum of the combustion heat values of its constituent elements. Thus, according to his ideas, the heat value of formic acid (CO_2H_2) should be equal to the combustion heat values of H and C. This, however, is not the case; for the heat value of $2H(2H + O = H_2O)$ is 683 calories, per gram mol., and of $C(C + O_2 = CO_2)$ is 943 calories, whereas the heat value of $CO_2H_2(CO_2H_2 + O = CO_2 + H_2O)$ is only 694 calories. The difference between the combustion heat value of CO_2H_2 and the sum of the heat values of H_2 and C is known as the heat of formation. That is, it is the heat developed and set free when the elements were combined to form the compound.

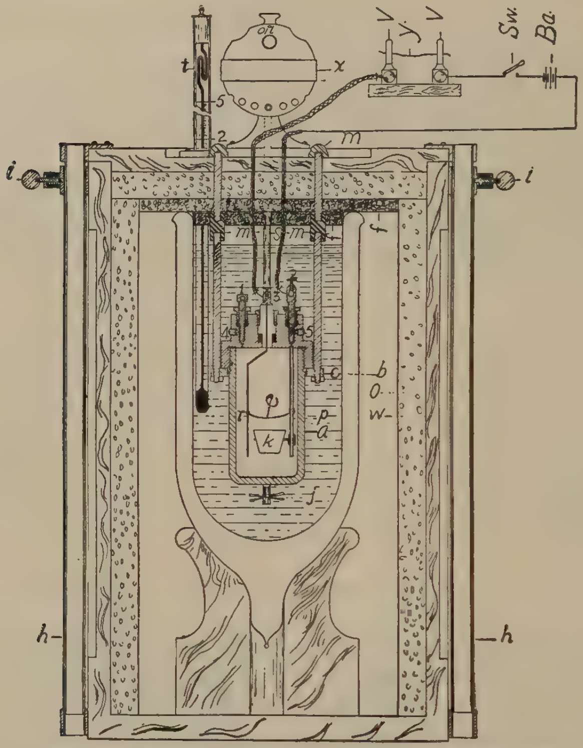

FIG. 197.—Bomb calorimeter (Riche). The food is placed in *k*, and is ignited by sending a known amount of current through *e*. *a*, Bomb; *b*, vacuum cup; *c*, split ring; *e*, platinum wire; *f*, felt; *h*, brass tube for support of cover; *i*, spring stops; *j*, stirrer; *k*, nickel capsule; *m*, fibre; *o*, sheet cork; *p*, platinum tube; *r*, platinum rod; *s*, stirrer rod; *t*, thermometer; *v*, fuse wire posts; *w*, wooden box; *x*, motor; *y*, fuse wire; *Sw*, switch; *Ba*, storage batteries; 1, 2, valve screws; 3, insulated post; 4, 5, inlet screws. (Jour. Amer. Chem. Soc., 1913, XXXV, 1747.)

Calorimetry of Foods.—All foodstuffs are organic compounds of this sort, but most of them are much more complex in their structure than formic acid. The combustion heat value of a substance is determined by burning it in an atmosphere of pure oxygen, in an apparatus known as a bomb calorimeter, of which there are many different forms. One of the most recent forms is shown in Fig. 197.

The subjoined table gives the combustion heat value of some of the most important foodstuffs:

Table 2.—Heat Value of 1 Gm. of Each Substance

Substance	Stohmann	Berthelot	Rubner	F. G. Benedict
Glycerin	4.316	....	.....	4.323
Glucose	3.743	3.762	.....	3.739
Levulose	3.755	.....	.....	3.729
Galactose	3.722			
Cane sugar	3.955	3.962	4.001	
Milk sugar	3.737	3.777	.....	3.737
Maltose	3.722	.....	.....	3.776
Dextrin	.....	4.119		
Starch	4.183	4.228		
Palmitic acid	.....	9.265–9.369	9.745	9.318
Stearic acid	.....	9.429–9.549	9.745	9.499
Oleic acid	.....	9.511	9.334	9.423
Animal fat	9.500			
Butter	9.231			
Vegetable oil	.....	9.520		
White of egg	5.735	5.687		
Yolk of egg	5.841			
Beef (ext. free of fat)	5.721	5.728	5.778	
Veal	5.663			
Casein	5.850	5.626		
Peptone from fibrin	5.942			
Glycogen	.....	.....	.....	4.227
Alanin	.....	.....	.....	4.401
Asparagin	.....	.....	.....	3.065
Aspartic acid	.....	.....	.....	2.882
Creatin	.....	.....	.....	4.240
Creatin	.....	.....	.....	4.988
Cystin	.....	.....	.....	4.137
Glutamic acid	.....	.....	.....	3.662
Glycocoll	.....	.....	.....	3.110
Tyrosin	.....	.....	.....	5.915
Alcohol	.....	.....	.....	7.104
Lactic acid	.....	.....	.....	3.615

If the end-products of oxidation were exactly the same in the body as in the calorimeter, the amount of heat produced by these substances when they are oxidized in the body should be the same as when they are burned in pure oxygen. This, in fact, is the case normally with all the pure carbohydrates and fats; for the end-products of oxidation in both instances are only CO_2 and H_2O. With the nitrogenous foods (proteins, extractives) the physiological heat value should be less than the calorimetric heat value for the reason that the body does not oxidize nitrogen completely. If it should do so, the end-product (nitric acid) would be very harmful to the body and would require to be neutralized in some way. Those products which represent the partially oxidized nitrogen of the proteins of the food are excreted in solution in the urine (urea, uric acid, etc.). Hence the physiological heat value of any protein (*e.g.*, washed meat) may be found by subtracting the combustion heat value of its nitrogenous waste products from the combustion heat value of the meat itself. To make the determination still more exact, it is necessary to make certain other corrections. Thus, while meat or casein, for example, may be completely digested and absorbed, they always occasion a loss of nitrogenous material from the bowel, which represents the unabsorbed residues of the digestive juices. The heat value of the feces, therefore, should be subtracted. Then there are certain small heat fractions lost in the imbibition of water by the protein and in the solution of the urea, etc., in the urine. Making all these corrections for lean meat, extracted free of fat and dried, Rubner[155] obtained the following from a feeding experiment with the dog:

		CALORIES
100 gm. fat-free, dried meat, combustion		535.5
Urine	112.9 cal.	
Feces	16.8 cal.	
Imbibition of water	2.7 cal.	
Heat of solution	2.0 cal.	
	134.4 cal.	134.4
Difference		400.1

The heat value to the dog's body, therefore, was 4.0 calories per gram. Rubner had previously determined the dynamic equivalents of the different foodstuffs in terms of each other; thus: 100 gm. fat are equal in heat value to 211 gm. of protein, 232 gm. of starch or 234 gm. of cane sugar. Later he published the following as the physiological heat values of the three principal foodstuffs:

1 gm. protein	4.1 calories
1 gm. starch or sugar	4.1 calories
1 gm. fat	9.3 calories

These values are now generally employed, although upon the assumption that all the food materials are first transformed into similar substances of the human organism it would be necessary to employ the factor 9.54 calories for fat, and upon the assumption that the nitrogen of the feces does not represent metabolized protein, the factor 4.4 calories would be more correct for the human body. However, the direct determination of oxygen absorbed has made these factors unnecessary for computation of the heat production of the body even by the indirect method (see below).

Calorimetry of Animals and Man. *Indirect Calorimetry.*—With the correct determination of the calorimetric heat values of the simpler foodstuffs, it became possible to determine the total heat production of the human body. Pettenkofer and Voit,[138] under the patronage of the King of Bavaria, had constructed in Munich in 1865 a respiration apparatus which enabled them to estimate the products of respiration from an adult man in 24-hour periods. By collecting all the other excreta, they then were able to compute the total loss of the different elements from the body. Knowing the total nitrogen elimination from the body, by multiplying this amount by 6.25 they obtained the amount of protein used up. From the total amount of carbon eliminated they were able to calculate the amount of the non-nitrogenous materials consumed. Knowing that proteins contain 3.28 times as much carbon as nitrogen, one deducts first the quantity of carbon belonging to protein. If no food has been ingested during the time of the experiment, nor for 24 hours before, it is assumed that all the rest of the carbon came from fat.* Dividing the remainder of the carbon by 0.76, the percentage of carbon in fat, one obtains the number of grams of fat. If food is taken, containing only protein, or only fat or only protein and fat, the same calculation suffices to give the total amount of each foodstuff oxidized. Should the food contain carbohydrate, it is necessary to know the number of grams of carbohydrate absorbed. Since it is known that carbohydrate is oxidized in the body more readily than fat, it is assumed that all of this carbohydrate absorbed would be oxidized before any fat is drawn upon. Deducting from the total carbon excreted, first the carbon of protein, then the carbon belonging to the amount of carbohydrate absorbed, what remains is again counted as carbon of fat. In this way Pettenkofer and Voit computed the amounts of the different foodstuffs destroyed in the body under different conditions. But it was not until Rubner had perfected his method of determining the heat values of the foodstuffs, about 1885, that it became possible to compute the total heat production. Taking the figures which Pettenkofer and Voit had found from a fasting man, namely, 70.8 gm. protein and 222 gm. fat, as the amount destroyed in 24 hours, Rubner multiplied these amounts by the physiological heat values of protein and fat respectively, and learned that the man, while fasting, had produced in his body 2355.8 calories of heat energy in 24 hours, or about 33 calories per kilogram of net body-weight. This method of computing the heat production is known as the method of *indirect calorimetry.*

The amount of oxygen necessary for the oxidation of the indicated quantities of the foodstuffs consumed can readily be calculated from the known average composition of the protein, fats and carbohydrates. The only method of checking this result, however, in the procedure of Pettenkofer and Voit, consists in subtracting from the final weight of the subject plus the weight of the excreta, the original weight of the subject plus the weight of the ingesta. The difference should equal the weight of the oxygen absorbed and united with the combustible compounds. While this method of estimating the oxygen absorption of the subject is not very exact, it enabled Pettenkofer and Voit to learn positively that very little, if any, carbohydrate was oxidized in the body of their fasting subject.

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* It is now known that this is not strictly correct; for glycogen is burned as late as the thirteenth day of fasting.[12]

Respiratory Quotient.—This, they knew from the respiratory quotient. This term is applied to the quotient expressing the relation ship between the volume of carbon dioxide eliminated by the breath and the volume of oxygen absorbed therefrom. The value of the quotient $\frac{CO_2}{O_2}$ varies with the kind of foodstuff being burned, because the amount of oxygen already present in the compound is different. With carbohydrate the H and O are present in the proper proportion to form water (*e.g.*, $C_6H_{12}O_6$). Oxygen is required, therefore, only to satisfy the combining power of carbon. Hence, the R. Q. would be equal to unity. Thus: $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$. The number of molecules of O_2 absorbed in this reaction being equal to the number of molecules of CO_2 produced, the R. Q. would be 1. Fats and proteins contain relatively more C and less O than do carbohydrates. Hence relatively more O is required for their combustion, whether in the body or in the calorimeter. The average value for fats is commonly given as 0.71 and for proteins 0.78 to 0.80 depending upon the analysis accepted and the factor allowed for non-absorption. This value for fat is obtained from the analysis of 76.1 per cent. C., 11.8 per cent. H, and 12.10 per cent. O in fat. One gram of such a material would require 1,990.8 c.c. of oxygen for its combustion and would yield 1,420.4 c.c. of carbon dioxide. In the case of their fasting individual, Pettenkofer and Voit found a R. Q. of 0.69, which indicated clearly enough that nothing with an oxygen content as high as that of carbohydrate could have taken must part in the oxidation. The R. Q. of a man on an average mixed diet is in the neighborhood of 0.8.

Direct methods for the determination of the oxygen absorbed are now in use. The method originally devised by Regnault and Rieset and adapted to the calorimeter by Atwater and Benedict,[3] consists essentially in the maintenance of a constant tension inside the respiration chamber by admission of oxygen from a cylinder, to replace the oxygen used up by the subject. In this form of apparatus the same air is circulated round and round through the respiration chamber and the absorbers for the removal of carbon dioxide and water. If the system contains at the end of an experimental period the same quantity of residual CO_2 and H_2O as at the beginning, and oxygen is admitted, until the atmosphere contained in the system has the same tension as at the beginning, then the loss in weight of the oxygen cylinder gives the weight of oxygen consumed by the subject. The oxygen may also be measured directly as it is admitted, by a gas meter.

Knowledge of the oxygen absorbed makes it possible to determine the amounts of the different foodstuffs oxidized more accurately than by the method of Pettenkofer and Voit. The method of Zuntz and Schumberg[209] is as follows:

All calculations on the basis of one hour.

The N in the urine (per hour) (a) × 2.56 = C from protein in the respiration.

The CO_2 output in grams per hour × $\frac{3}{11}$ = C output in grams per hour.

The C of respiration − C of protein in respiration = C of carbohydrate and fat in respiration (*b*).

N in urine × 8.45 = O from protein in respiration.

Total O absorbed − O from protein = O absorbed for carbohydrate and fat (*c*).

The O for oxidation of 1 gram of fat = 3.751 (average).

The O for oxidation of 1 gm. of CH = 2.651 (average).

Let x = number of grams C from fat (1 gm. C from fat = 12.3 calories).

Let y = number of grams C from CH (1 gm. C from CH = 9.5 calories).

$x + y = b$

$3.751x + 2.651y = c$

Solving for x and y

(1 gm. N from Prot. = 26.0 calories).

$a \times 26$ = calories from Prot.
$x \times 12.3$ = calories from fat.
$y \times 9.5$ = calories from CH.
Total = calories per hour.

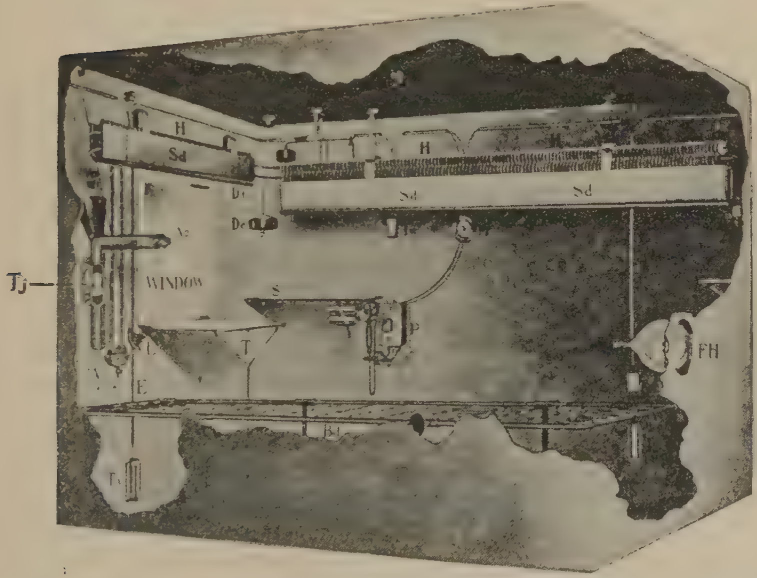

FIG. 198.—Interior of chamber of respiration calorimeter showing arrangement of heat-absorbing system (H, H, H), the shields (Sd, Sd, Sd), the ventilating air-pipes (A, A_2), bed (Bd), table (T), telephone (P). (Atwater-Rosa, Carn. Inst. Publ. #42, Wash., D. C., 1905.)

Direct Calorimetry.—The first to make successfully a comparison of the heat production as calculated from the excretory products, with the heat production as directly measured was Rubner, in 1891. In his laboratory at Marburg he constructed a calorimeter* consisting of a closed cage large enough to contain a large dog and immersed it in a large copper water bath—all but the opening left for access to the cage. The calorimeter was ventilated on the same principle as the Pettenkofer-Voit respiration apparatus. Heat was measured not by collecting it in water but by recording its effect in expanding a closed volume of air. A calorimeter of this sort where the heat is allowed to escape is called an *emission calorimeter*.

The results of Rubner's experiments reported in 1894 are as follows:

Table 3.—Comparison of Direct and Indirect Calorimetry

Number	Animal	Food per day	Number of days	Heat prod. calculated	Heat prod. measured	Difference in per cent.
1	Dog I.	Fasting	5	1,296.3	1,305.2	+0.69
2	Dog II.	Fasting	2	1,091.2	1,056.6	−3.15
3	Dog I.	390 gm. meat	1	329.9	333.9	+1.20
4	Dog I.	40 gm. lard	5	1,510.1	1,495.3	−0.97
5	Dog I.	80 gm. meat 30 gm. lard	12	3,985.4	3,958.4	−0.68
6	Dog I.	same	8	2,492.4	2,488.0	−0.17
7	Dog I.	350 gm. meat	6	2,249.8	2,276.9	+1.20
8	Dog II.	580 gm. meat	7	4,780.8	4,769.3	−0.24
			46	17,735.9	17,683.6	−0.30

In a total of 46 days of experimentation, with his animals on various kinds of food, Rubner thus found a difference of only 0.3 per cent. between the heat production, as calculated, and the heat production as directly measured. This proves, conclusively, the correctness of the physiological heat values assigned by Rubner to the three classes of foodstuffs and proves also that the energy set free in their oxidation (when the animal is doing no external work), whatever transformations it may undergo in the body, finally leaves the body as heat. In other words, all the available energy which entered the body in potential form had been recovered as heat, and the applicability of the law of the conservation of energy to the animal body was thus demonstrated.

In 1892 Atwater and Rosa, in this country began the construction of a calorimeter at the Wesleyan University, Middletown, Conn., which, it was planned, should measure directly the heat production of a man. The first results were published in 1897 in a Bulletin of the U. S. Dept. of Agriculture, which had extended financial assistance to the investigators and subsequent results in numerous Bulletins published since.

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* This was by no means the first animal calorimeter. The first was constructed in Glasgow by Adrian Crawford in the year 1777. Lavoisier and LaPlace used an ice calorimeter in the same year, but no description was published until 1780. Several other French scientists, notable DuLong and DePretz (1823) D'Arsonval (1884) & Richet (1884), also had preceded the Germans in the use of calorimeters for the study of heat production in the animal body.

The principle of this apparatus, so far as its heat-measuring features were concerned, was different from that of Rubner. The chamber (2.15 meters long × 1.22 meters wide × 1.92 meters high) was built of copper and was placed inside a succession of walls, consisting of zinc and wood, enclosing dead air spaces. Between the copper and zinc walls were placed thermo-electric junctions so that at any moment it could be determined whether heat was leaving the chamber or entering it through the walls. Outside the zinc walls were placed cooling tubes carrying a stream of water of suitable temperature and wires which could be heated by passing through them a current of electricity. The space immediately adjoining the copper wall could, therefore, be cooled or warmed as required to keep the inner space next the copper wall adiabatic. With no heat leaving or entering the chamber through the wall and with the air leaving and entering properly recorded, the bulk of the heat produced by the subject was absorbed by a stream of cool water circulated through a series of copper pipes in the upper part of the chamber. The temperature of this water as it entered and left the chamber was recorded every two minutes by a person who also controlled, through electric appliances, the condition of the walls. The amount of water passing through in a given time was determined by weighing. The number of calories of heat carried away was, therefore, found by multiplying the number of kilograms of water which had circulated by the average difference in temperature noted between the entering and leaving water. The total heat produced is found by adding to this the amount carried away by evaporation of water and making a correction for changes in the body temperature.

By means of this and other calorimeters constructed on the same principles agreement between the direct and indirect measurements quite equal to those of Rubner for the dog has now been obtained not only for the adult man but also for the baby.

Influence of Muscular Work on the Heat Production.—When Liebig had completed his classification of the foodstuffs, and had found that all animal tissues contained proteins, *i.e.*, are nitrogenous, he suggested that the excretion of nitrogen by the animal might be used as a measure of protein destruction in the animal's body. Carl Voit, who had been a pupil of Liebig, was the first to put this suggestion to practical use. Among many other important facts, regarding the metabolism of proteins, Voit discovered that, contrary to the teaching of Liebig, the protein of the body is not the source of the muscular energy; for, during muscular work, no more nitrogen is eliminated than in muscular rest. Since it had been known from the time of Lavoisier that muscular exercise increased the heat production, it followed, from the observations of Voit, that the non-nitrogenous foodstuffs must be the source of the extra heat production as well as of the energy of muscular contraction. This fact is now thoroughly established by almost numberless experiments. An illustration may be taken from the work of Atwater cited above. A subject doing work on the bicycle ergometer produced in 24 hours 5,100 calories of heat, of which 434 calories came from the protein (N × 6.25 × 4.1). In muscular rest this same individual produced only 2270 calories, of which 400 came from protein. The day's work had increased the total heat production 2830 calories, but the heat from protein had been increased only 34 calories. All of the rest, 2800 calories (nearly), came from non-nitrogenous food.

Since the time of Helmholtz a question of great interest to physiologists has been that of the mechanical efficiency of the human body. By this is meant the relationship of work accomplished to the extra energy consumption necessitated by the work. Engineers find that it is an exceptional steam engine which can convert 15 per cent. of the potential energy of the fuel into effective mechanical work. The internal combustion engine may occasionally reach an efficiency of 30 per cent. A combination of internal combustion and steam, as in the Still-Diesel engine, may reach an efficiency of 40 per cent. The remaining 60 to 85 per cent. is lost as free heat. The heat of combustion in the internal combustion engine of an automobile, however, can be turned to account in cold weather; hence is not all wasted. This the human body does also at a very considerable physiological saving.

Various estimates have been placed upon the mechanical efficiency of the human body, depending upon the type of apparatus employed in its measurement and dependent also upon the type of work performed. Helmholtz[72] calculated from data obtained by Smith,[184] Dulong,[52] and Depretz[47] that the efficiency was about 20 per cent. Laulanié[103] found in turning a wheel with a brake, an efficiency of from 9 to 23 per cent. depending upon the amount of load imposed with the brake. During[53] estimates it at from 19 per cent. for a brake ergometer to 46.5 per cent. for a tread mill—with an average for tread mill work of about 31 per cent. L. Zuntz made out an efficiency of 28 per cent. in bicycle riding; but Benedict and Carpenter[14] using the same type of work, only changing the bicycle to a stationary ergometer found an average of only 21.5 per cent., a figure which has been substantially confirmed in a more recent and elaborate study by Benedict and Cathcart.[17]

All these results apply to the mature human subject. It is not known as yet whether the youthful human subject works with a greater or less efficiency in such commonplace types of work as carrying the body forward with the leg muscles, or whether mechanical efficiency bears any relation to surface area. One can scarcely speak of muscular efficiency in the nursing infant for there is no means of converting his random muscular motions into effective external work (p. 607).

Influence of External Temperature on Heat Production in Warm-blooded Animals.—It has been noted above that the influence of external temperature on the heat production of cold-blooded animals, as in plants, follows Van't Hoff's law. In warm-blooded animals, however, with the development of the capacity to regulate the body temperature independently of the surrounding medium, this law is to some extent reversed, so that the lower the external temperature becomes the greater is the heat production. This is necessarily the case if the body temperature is to be maintained. Confirming the original observation of Lavoisier that more heat is produced in the human subject when the external temperature is low, C. Voit[198] exposed a man in light clothing in his respiration apparatus to different temperatures and found that, as the temperature fell, the metabolism increased independently of any muscular motions. Rubner[156] carried this line of investigation much farther, using dogs and guinea pigs, and formulated his laws of the chemical and physical regulation of the body temperature. In brief, these laws are: (1) That, from a temperature of about 30°C. downward, the body temperature is regulated chiefly by varying the heat production (chemical regulation). Heat loss is regulated, to some extent, by decreasing the amount of blood brought to the surface. (2) From 30°C. upward the body temperature is regulated chiefly by varying the amount of water evaporated from the surface and by increasing the amount of blood brought to the surface (physical regulation).

The conclusions of Voit and Rubner with regard to the effect of cold as such have frequently been called in question, the contention being that if visible shivering and increased tonus of the muscles are avoided no more heat is produced at low temperature. Loewy[102] and Johansson[90] conducted carefully controlled respiration experiments by two different methods with a view to the determination of the pure effect of cold. The former employed sixteen different subjects, cooling the body not only by exposure to a temperature of 12 to 16°C., but also by evaporation of water, alcohol and ether from the skin. The latter performed experiments upon himself as subject after acquiring the power to suppress all shivering or even increased tonus, when the naked body was exposed to a room temperature of 13 to 20°C. Both observers found that there was no increase in the elimination of carbon dioxide when the muscular factor was really ruled out. Uncontrolled shivering in Loewy's experiments produced an increase of 100 per cent. in the metabolism. Lusk[104] later found that a man immersed for a few minutes in a cold bath at 8°C. would, immediately thereafter, shiver enough to increase his metabolism 180 per cent. above the normal. It is well known that such shivering can easily be cured by voluntary muscular exercise and it is for his reason that one walks more briskly on a cold day. In the recent training camps of the army it was noticed that soldiers are much more inclined to frolic or "play horse" in bracing cold weather. Mainly on this account, but partly also, no doubt, on account of increased heat loss from exposed parts and through the clothing, soldiers eat on the average about 400 calories more[130] in winter than in summer.

How Heat is Lost From the Body.—In general, there are four main avenues of escape for the heat which is produced in the body of a warm-blooded animal: (1) Warming the food and air which enter the body; (2) vaporization of water and setting free CO_2 in the lungs; (3) evaporation of water from the surface of the body; (4) radiation and conduction from the surface of the body.

Rubner has made the following calculations for a man producing 2700 calories daily:

	Calories
1. Warming food and drink to body temperature	42
2. Warming air from 17.5 to 30°C	35
3. Evaporation of water from lungs and skin	558
4. Heat equivalent of external work done	51
5. Loss by radiation from entire surface of body	1181
6. Loss by conduction to air from entire surface	833
	2700

Atwater, in his calorimetric studies, made the following estimations:

I. Resting Man, Mean of 14 Experiments Comprising 42 Days:

	Calories
1. Heat loss by radiation and conduction	1683
2. Heat loss by urine and feces	31
3. Heat loss by evaporation from lungs and skin	548
Total	2262

II. Man at Work, Mean of 20 Experiments Comprising 63 Days:

	Calories
1. Heat loss by radiation and conduction	3340
2. Heat loss by urine and feces	26
3. Heat loss by evaporation from lungs and skin	859
4. Heat equivalent of muscular work	451
Total	4676

It is evident, from these estimates, that fully 80 per cent. of all the heat produced in the body is lost through the skin.

The Law of Surface Area.—Closely related to this matter of the loss of heat through the skin is the relationship of heat loss to heat production, known as the law of surface area, first enunciated over 80 years ago by certain French writers. To quote one of the earlier communications, "As the heat loss is proportional to the extent of free surfaces and these latter are to each other as the squares of their homologous sides, it follows of necessity that the quantity of oxygen absorbed, or, what amounts to the same thing, the heat produced on the one hand and lost on the other is proportional to the square of the corresponding dimensions of the animals which one is comparing."[150] The first experimental evidence of a relationship between skin surface and the food requirement of animals seems to have been furnished by Müntz[121] who in 1879 investigated the maintenance ration of horses. Emphasizing the part played by the surface he says: "A notable part of the food certainly is consumed to maintain the vital heat which has a tendency constantly to be lost by radiation or conduction to the surrounding medium. Another cause of cooling is cutaneous evaporation which is a function of the surface if it is not directly proportional thereto. The evaporation produced by the organs of respiration may equally be regarded as having a relation to the surface of the body rather than to the weight. We are then by these considerations in position to admit the preponderating influence of surface upon the apportionment of the maintenance ration."

This law of surface a few years later was placed upon a firmer basis by researches of Rubner[154] upon dogs and of Richet[148] upon rabbits.

A small animal has a greater surface, in proportion to its weight, than has a large animal. This will be clear from the following illustration. Suppose we have two spheres of two and four centimeters diameter. The surface of the smaller would be 12.56 square cm. and of the larger 50.24 square cm. The volume of the first would be 4.18 c.c. and of the latter 33.49 c.c. The surface of the smaller, in proportion to its volume, therefore, would be as 3:1, while of the larger it would be only as 1.5:1. Since, now, more than four-fifths of the animal's heat escapes through the skin by one physical means or another, it is clear that heat must be produced in proportion to the surface rather than in proportion to the mass, if the body temperature is to be maintained. Hence, if two animals, with similar coats of fur, had skin surfaces that bore to each other the relation of these spheres, the smaller animal would produce twice as much heat per unit of weight as the larger. Rubner found that the average heat production per square meter of body surface for man, dog, rabbit, guinea pig, and mouse was 1,088 calories with variations of -104 calories to $+103$ calories, *i.e.*, of about 10 per cent. either way.

Measurement of the Surface Area.—Several methods have been proposed for determining the surface area of the human subject. The first was that of Meeh[114] who marked out some parts of the body, which were favorable for the purpose, in geometrical figures, covered them with transparent paper and made tracings of the figures. The areas of these figures were then calculated or determined by weighing the paper. Other parts of the body were measured directly by wrapping with millimeter paper.

Bouchard[35] suggested a plan which was later improved upon by DuBois and DuBois,[51] namely of clothing the body in tights made of some thin inelastic material which could be weighed. D'Arsonval clothed a man in silk tights and after charging the covering with electricity, determined the surface relative to a metal plate of known area by releasing the charge as from a Leyden jar. Lissauer[100] measured the surface of dead infants by covering the skin with adhesive material, applying silk paper, and then measuring the area by means of a planimeter. The measurement was accomplished by DuBois and DuBois in the following manner. A close-fitting union suit was put on, and over this an inelastic covering was produced by pasting upon it strips of adhesive paper. Instead of attempting to weigh the covering itself, the "model" of the body was cut up into pieces which would lie out flat so that its area could be determined by photographing it upon sensitive paper. The total area was then found by weighing the photographic silhouettes and comparing with the weight of a unit area of the same sensitive paper. The areas of the several members of the body as measured were then compared with the areas as given by multiplying their lengths by sums of measurements representing circumferences. For example, the area of the arm was given by multiplying the length from the outer end of the clavicle to lower border of radius F, by the sum of the three circumferences at: Upper border of axilla G; largest girth of forearm H; smallest girth of wrist I. This calculated area compared with the actual area for several individuals gave a factor which, used with the product just given, made up a so-called linear formula for the arm; thus: $F \times (G + H + I) \times 0.558$. The several subformulæ added together could then be employed for measuring the surface of the entire body.

This method resembles the one proposed by Roussy[153] in which the surface was given by multiplying the mean perimeter *pm* by the mean peripheral total height (*Hm*); thus $S = Pm \times Hm$. The first factor was found by taking the mean of 29 different circumferences (Fig. 200), while *Hm* is the sum of the three partial heights: (*a*) head, neck and shoulders; (*b*) trunk and lower extremities; and (*c*) upper extremities.

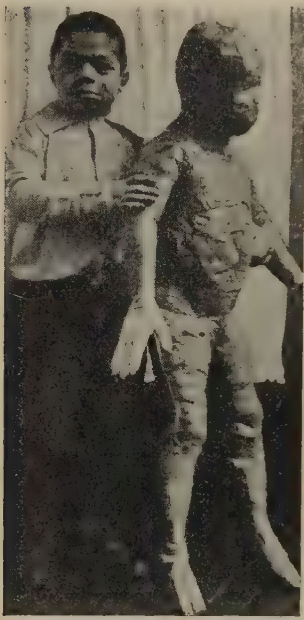

FIG. 199.—A Cretin, Benny L., and his surface mold. (DuBois, Archives of Int. Med. Chicago, 1915, XV, 872.)

From his measurements Meeh derived a formula based upon the well-known relationship of surface to mass of similar solids; namely, that the former varies as the two-thirds power of the latter. By employing a constant, 12.3, Meeh found that the formula $S = \sqrt[3]{w^2}$ gave results within seven per cent. of those determined by actual measurement. DuBois found an agreement between measured and calculated values for five cases within two per cent. Later[50] the measurements were greatly simplified and a formula containing total height, weight and certain constant factors was devised. This is known as the height-weight formula, $A = W^{0.425} \times H^{0.725} \times C$, where A is surface in square cemtimeters, H the height in centimeters and W the weight in kilograms. C is a constant 71.84.

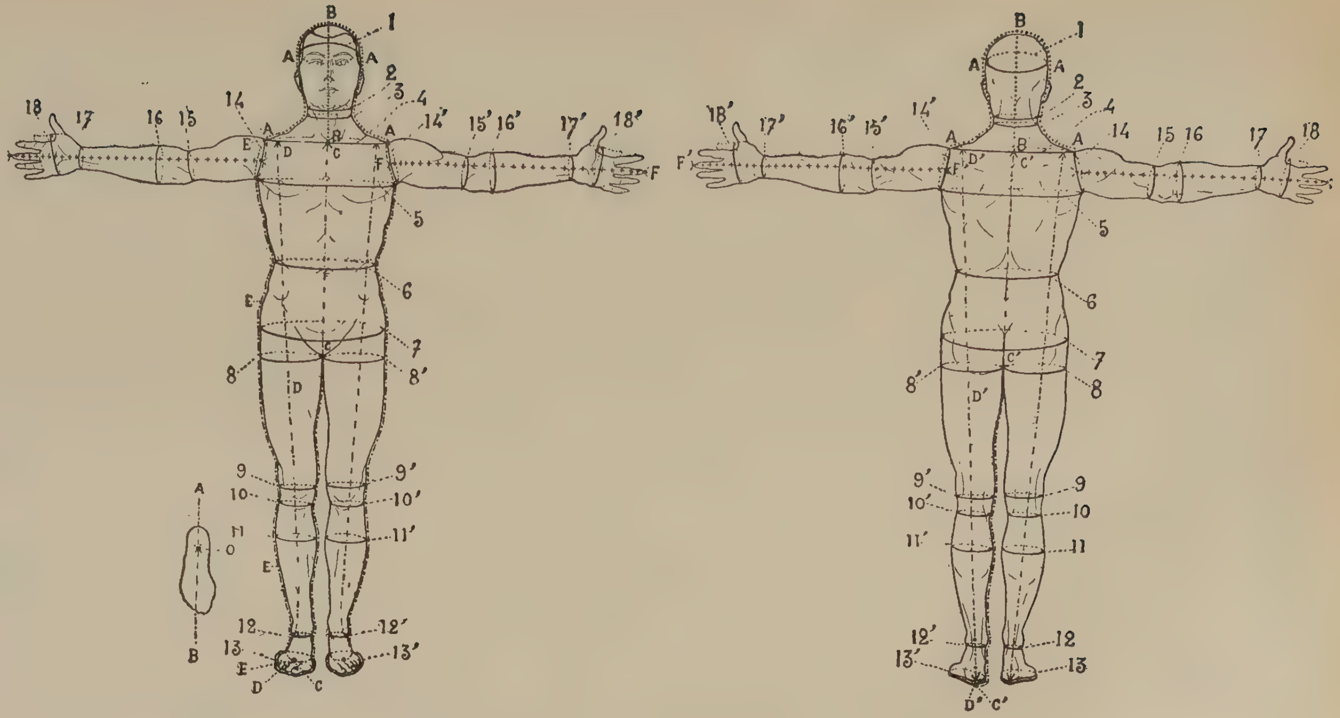

FIG. 200.—The surface of a man's skin is equal to the product of his mean perimeter (Pm) by his peripheral mean total height (Hm): s = Pm × Hm. Pm is obtained as the mean of 29 different circumferences including the slimmest and most robust. Hm is the sum of the three mean partial heights: a, head, neck and shoulders; b, trunk and lower extremities; c, upper extremities. (After Roussy. Compt. Rend. l'Academie de Sciences, July 17, 1911—T153, p. 206, both figures.)

Further discussion of the surface areas of infants will be found in later sections (pages 600, 640).

Protection Against Heat Loss.—Practically all warm-blooded animals have some means of protection against excessive heat loss. The most important of these are the natural coverings (hair, fur, feathers) on the skin and subcutaneous fat. The chief value of hair, fur, etc., in this connection lies in the large quantity of stagnant air which they occlude. This air, being stagnant, retards the conduction of heat away from the body. Subcutaneous fat, on the other hand, is a poor conductor of heat, a layer only 3 mm. thick having been found to diminish the heat loss in a unit of time more than 50 per cent. Subcutaneous fat is especially important for aquatic mammals, because the water wets the fur, driving out all the air.

The human body, not being provided with a complete natural coat of hair, requires the aid of artificial coverings in order to maintain its temperature in climates which average less than 27 or 28°C. Above this temperature, the naked body is able to regulate its temperature unaided. Clothes serve to diminish the movement of warm air away from the body, in the same way as hair, fur, and feathers do. It has been estimated that no less than 10 liters may be occluded by the meshes of a woolen suit of clothes, and some 10 to 20 liters more may be held in the spaces between different garments and between the garments and the body. Heat loss by radiation is also reduced by clothes, the exact effect depending on the conductivity of the material. The importance of artificial covering for the infant, whose heat-regulating mechanisms are not yet functional to their full capacity is at once apparent, especially in view of the enormously greater surface in proportion to weight of the infant's body (see discussion at p. 642).

Regulation of the Body Temperature.—It has been noted above (p. 524) that the body temperature varies between very narrow limits. This fact, in itself, is a proof that the mechanism of heat production is very nicely adjusted to the process of heat loss. How is this coöperation brought about? It has been shown that, when a man is subjected to an external temperature (bath) varying slowly between 34 and 37°C., the mechanism of heat loss (sweating) is brought into play when the body temperature (rectum) is raised on the average 0.34° and the mechanism of heat production (shivering) when the body temperature has fallen on the average 0.26°. Likewise, in muscular work, sweat breaks out when the body temperature has been raised on the average 0.43°. Whether the reaction in each case is brought about by the change in temperature of the blood and the direct stimulation of the sweat centers or the motor centers respectively, or by reflex stimulation of these centers through the cutaneous nerves, is not definitely known. There is much evidence that the corpora striata in the base of the forebrain contain a center which is particularly susceptible to changes in temperature and to mechanical stimulation.[105, 192]

Influence of Food on the Heat Production.—The observation of Lavoisier that the heat production was increased by taking food was confirmed by Pettenkofer and Voit, who found that the total metabolism of a dog was increased from 34.9 to 65 calories per kilogram as the result of eating about two and one-half pounds of meat. Feeding fat they observed no increase in the heat production unless the amount fed was far in excess of the body requirements. Feeding carbohydrate in the form of starch, they found that 3.79 gm. in the food increased the metabolism 17 per cent. over that of the starving animal. More exact information concerning the influence of carbohydrate came with the invention of methods by Zuntz and by Benedict by which the oxygen absorption could be determined, since, without this knowledge, it was impossible to distinguish the part taken by fat in the total heat production from that taken by carbohydrates. Magnus-Levy using the Zuntz method with human subjects, came to the conclusion, substantially in accord with those of Pettenkofer and Voit, namely, that moderate quantities of fat do not increase the heat production (absorption of oxygen), but that both carbohydrate and protein increase it considerably. Rubner, using only the excretion of CO_2 as the measure of heat production, formulated laws regarding the influence of different foods given to dogs, as follows: Since the different foodstuffs affect the heat production to a different degree, we may speak of their "specific dynamic action." The proper basis of comparison is the amount of heat produced by the fasting animal. Taking this quantity as the minimal requirement of the animal for energy (in potential form), and feeding this quantity in the form of different foodstuffs, the effect is for protein an increase in heat production of 30 per cent., for fat 11 per cent., for carbohydrate 5.8 per cent. In order to keep the animal in an energy equilibrium, therefore, it is necessary to feed him in protein 140 per cent. of the requirement, in fat 114 per cent., and in carbohydrate 106 per cent.[105]

Lusk[207] and his co-workers, using a small respiration calorimeter of the Atwater-Rosa-Benedict type suitable for studies on dogs, babies, or dwarfs, have demonstrated that the increased heat production after ingestion of proteins is due to the amino-acids into which the protein is broken up by digestion. It is, however, not the mere absorption of the amino-acids themselves, nor their direct oxidation which accelerates the metabolism, but the stimulating effect of the intermediate oxyacids which are formed from them. Quantitatively the results of these more modern researches confirm the conclusions of Rubner as to the specific dynamic effect of protein. These, however, relate to the dog. In man the dynamic effect is ordinarily not so great. The dynamic effect of protein in milk upon the metabolism of the infant will be discussed later (p. 634 *seq*). It need only be added here that protein which becomes a part of the body does not affect the heat production.

The dynamic effect of fat, it turns out, is not so high as Rubner found it, if reckoned for the entire day, but for individual periods up to six hours after feeding,[127] may increase the metabolism as much as 30 per cent., as contrasted with protein (meat) which may raise it to 42 per cent. Bloor[30] found that the fat in the blood also may increase up to six hours after feeding.

Following Rubner's fundamental observation on the influence of carbohydrate on the respiratory metabolism of a fasting dog, Magnus-Levy, Johansson, Dürig, and DuBois, made confirmatory observations on the human subject. One hundred grams of glucose causes an average increase of nine per cent. in the heat production of a man of 75 kg.; and 200 gm., one of 12.5 per cent. during three to six hours after the ingestion.[63] The same dose with a smaller man produces a proportionally greater acceleration of the metabolism.

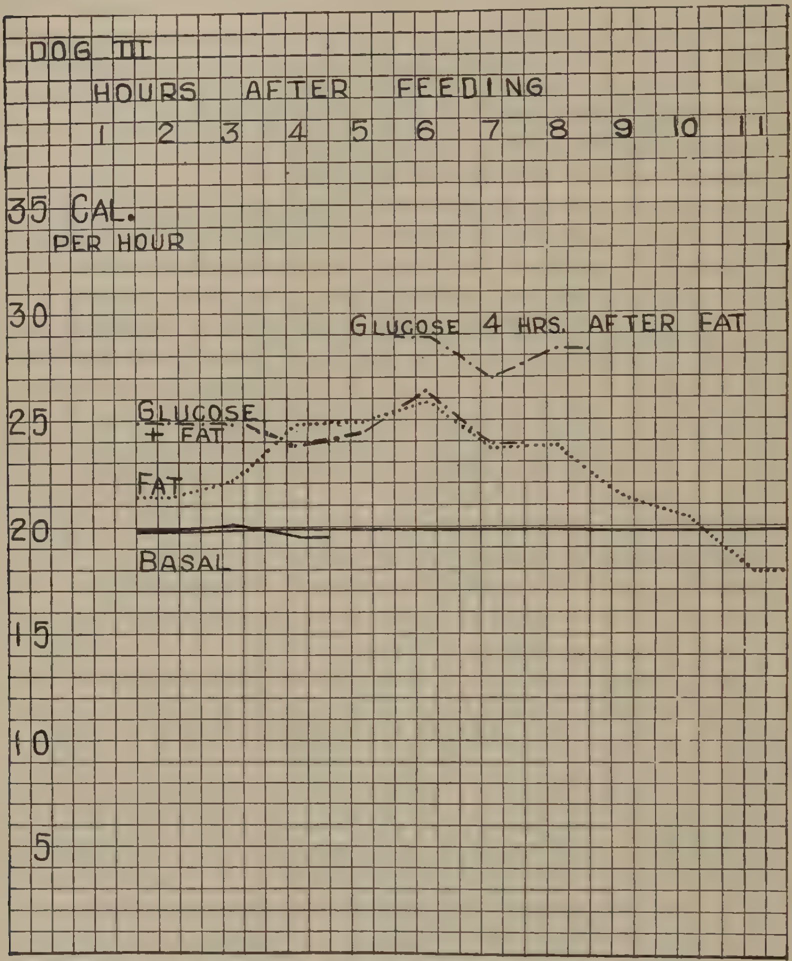

Fig. 201.—Heat production of a dog after giving: a, fat; b, glucose after fat; c, glucose and fat; showing summation. (Murlin and Lusk, Journ. of Biol. Chem., 1915, XXII, Chart I, p. 18.)

Lusk[54] and his pupils have found that the period of highest metabolism after heavy sugar feeding to dogs coincides with an osmotic dilution of the blood caused by the rapid absorption of the sugar, and a sudden fall in the metabolism coincides with a removal of sugar from the circulation by the liver and a rapid elimination of water through the kidney. Lusk believes, therefore, that the heightened metabolism following rapid absorption of fat or carbohydrate may be called a "metabolism of plethora,"[105] or, in words of one syllable, oil on the fire. Since a summation effect is produced when carbohydrate and an amino-acid, or both, are added at a time when fat is producing a maximal effect, and from other considerations which need not be entered into here, Lusk [105] infers that separate mechanisms exist within the body cells for oxidation of the several foodstuffs.

Basal Metabolism.—By way of summary of the preceding sections, one may say that the three factors determining the level of the energy metabolism in the normal organism are, muscular activity, external temperature, and food. A subject removed from the influence of these three factors would be (*a*) resting, (*b*) at a comfortable temperature, (*c*) several hours after the ingestion of food. The metabolism under these conditions would be at its lowest and is therefore called "basal metabolism."

It is the basal metabolism which is used in determining the effect of age, sex, body weight, stature, physical development, or of a disease or physiological defect upon heat production. The individuals used for establishment of a standard must be in a state of health which would be regarded as normal.

Influence of Physical Characteristics.—From an exhaustive biometric study of basal metabolism in the normal human subject, including some 250 adults and 100 infants, Harris and Benedict[70] have found that there is no very high degree of correlation between heat production and the heart activity as measured by pulse rate unless correction is made for body weight or body surface. "The most intimate correlations are obtained when correction for body size is made by expressing heat production in calories per square meter of body size." As regards the effect of body weight upon gaseous exchange, the same authors find that an increase of 1 kg. of weight in adult men increases the consumption of oxygen on the average 2.27 c.c. per minute and the carbon dioxide elimination 1.89 c.c. per minute. For women the values are 1.17 c.c. O_2 and 1.02 c.c. CO_2 per kgm. and minute. There is also a distinct and independent correlation between stature and gaseous exchange, but this is not so close as with body weight. A kilogram of body weight added in the adult increases the total heat production per 24 hours on the average 8.2 calories for women, and 15.8 calories for men.

Harris and Benedict have also subjected the body-surface law of Rubner to a critical biometrical study and have reached the conclusion that the correlations between body-surface and heat-production in normal adults are of about the same magnitude as those between body weight and heat production. "These results do not, therefore, justify the conclusion that metabolism is proportional to body surface and not proportional to weight." The closer agreement between heat production by different individuals and their surfaces than between heat production and body weight is not, in their opinion, due to any causal relationship between heat loss and heat production as a mechanism for preservation of body temperature, but in part, at least, proceeds from the fact that, body surface being proportional to the two-thirds power of weight is less variable than weight, and the ratio of total heat production to body surface is therefore less variable. The authors draw attention to the fact also that at least 25 per cent. of the heat loss occurs through vaporization of water from the skin and lungs, and not by radiation and conduction. Nevertheless they are obliged to admit that both upon the score of correlation coefficients and of equations of prediction, the body surface is a "somewhat better" basis of comparison than body weight. These studies, it should be noted, were made upon adults only and no effort was made to comply with Rubner's postulate of like physiological states as a condition precedent. Moreover, while quoting favorably the observations of Dreyer, Ray, and Walker[48] to the effect that blood-volume, area of cross-section of the trachea and area of the cross-section of the aorta, are proportional to the two-thirds power of the weight, they make no reference to the fact that these are the very factors which determine vaporization from the lungs under similar physiological states. Vaporization of water from the skin in different individuals of the same species under similar physiological states may likewise be proportional to surface. Finally, as Harris and Benedict seem to admit, and, as we shall see later in comparing the metabolism of the infant with that of the adult (p. 642), between individuals of the same species of "very different physical configuration," the body-surface law must be considered applicable.

Influence of Age on Basal Metabolism.—This subject is one of immediate interest in connection with the metabolism of infants. It will be discussed for the present, however, only from the general standpoint, reserving for a later section the significance of age among infants and children. DuBois[49] has recently assembled the data for the influence of time of life from birth to old age upon the total heat production. His chart in terms of calories per hour per square meter of body surface appears below. In considering the causes of the altered rate of heat production, one must bear in mind first the differences in body form which themselves affect the relationship of body surface to body weight, secondly, the specific influence of different organs which not only bear different relations as regards size, to the body as a whole, but probably in some instances also have quite a different coefficient of activity. Thus, in early life the liver and thyroid especially, both organs of high metabolic activity, are preceptibly larger in the relative sense than in adult life, and may be expected to play a larger part in the total chemical activity of the body. This may, to a large degree, account for the heightened metabolism of the infant when reckoned on the basis of a unit of surface. That the rate of growth itself, however, may be partly responsible, is evidenced by the fact that boys at the age of prepubescence, just when growth is accelerated, experience also a quickening of heat production. DuBois's results (p. 680) indicate that this may amount to as much as 25 per cent. over the normal level for adults. Whether the awakened activity of the internal secretory mechanism of the sex glands acts independently or only through its effect upon growth, can only be decided by experiments upon animals. The latest experiments of this kind by Murlin and Bailey[129] support the view of Richter that in the female at least there is an independent effect quite outside the effect upon muscular rest. The tendency to obesity following the menopause in women is to be explained, therefore, as due to the absence of a stimulus which was present so long as the ovary was active. Removal of the ovary has the same effect. The falling metabolism of old age is to be explained in part by the tendency to reduce muscular effort of all sorts to a minimum, this, in turn, being traceable probably to the absence of internal stimuli, whether reflex or chemical. The deposit of calcareous material in certain organs, which so frequently accompanies old age, may also of itself reduce their metabolic activity.

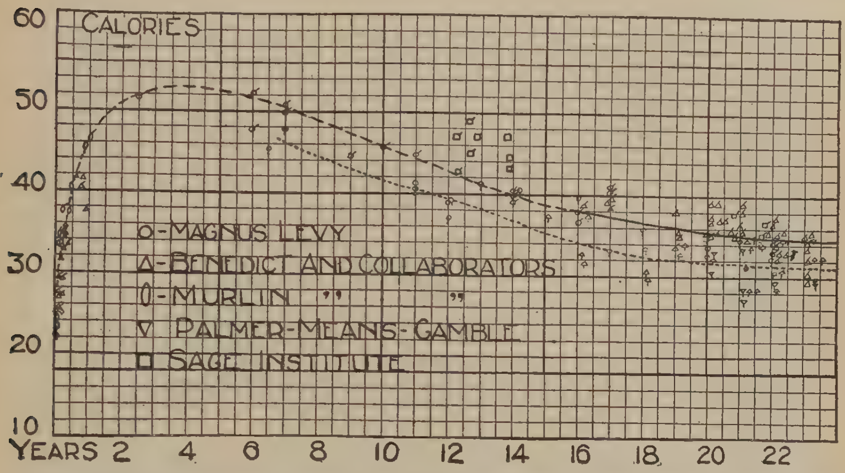

FIG. 202.—Variations of basal metabolism with age. Calories per square meter of body surface, Meeh's formula. . . . . shows average for males, . . . average for females. (DuBois, Archives of Int. Med., Chicago, 1916, xvii, Chart 2, p. 899.)

Statistically studied, the decrease in total heat production per 24 hours for each year of age is, according to Harris and Benedict,[70] 7.15 calories for their series of 136 adult men. For the 103 women it is 2.29 calories for each year of adult life. Upon the basis of a unit of body surface, the correlations with age "are of a more strongly negative character than the correlations between age and total heat production," which means that with each advancing year of life there is a heavier decline upon the basis of a square meter of body surface than upon the basis of total heat production. This conclusion is in accordance with DuBois's curve, though it does not give exactly the same rate of change. Their curves for all adults between 17 and 62 years of age are reproduced in Figs. 203, 204. The extreme fluctuations from the theoretical mean in the two sex groups are doubtless due to the fact that a very few individuals only of each sex between 45 and 49 years of age have been studied. The closer agreement as between different ages upon the basis of surface area than upon the basis of a unit of weight is striking.

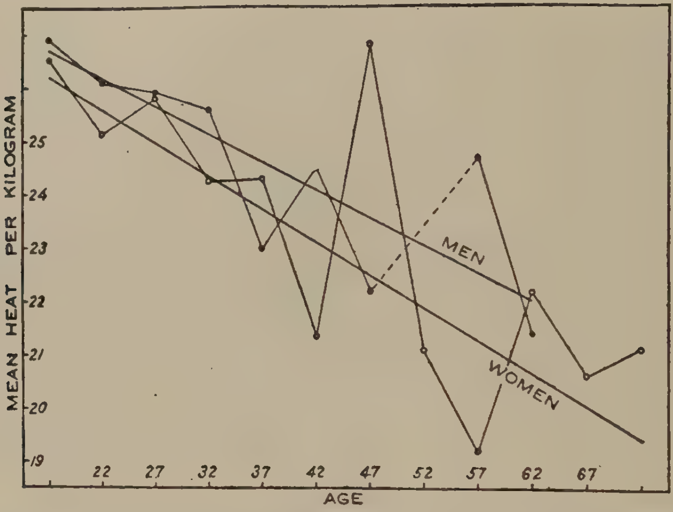

FIG. 203.—Mean daily basal metabolism per kilogram of body weight for men and women classified according to age. (Harris and Benedict, Carn. Inst. Publ. #279, Wash., D. C., 1919, Diagram 22, p. 120.)

The Influence of Sex.—Impressive also is the difference between the two sexes. DuBois[49] had already drawn attention to this difference in the first curve which he published showing the variation with age. His curves for the two sexes ran about the same distance apart (7 per cent.) as do the newer ones here reproduced. Twenty years ago Magnus-Levy and Falk found the difference between the two sexes both in early life and in advanced age about five per cent., but were of the opinion that in adult life the two sexes maintain about the same metabolism, consideration being had to difference in size and age. Harris and Benedict have analyzed the results of metabolism studies on the two sexes very exhaustively, making correction for body weight, body surface, age, and stature, and find that on every basis the metabolism for the woman is lower than that of men. Even when the theoretical heat production of the woman is calculated by inserting their actual physical measurements in equations based on the series of men (regarding the woman, that is, as a man of the size of the woman), the actual heat production is generally lower than the theoretical. Larger women show a relatively larger deficiency than smaller ones and the suggestion is made by the authors that the body weight is the primary factor in determining the deficiency. "The most critical test shows that when body weight, stature, and age are taken into account, women show about 6.2 per cent. lower metabolism than men."[70] The same sort of analysis made for newborn infants taken entirely from the Benedict and Talbot series indicates, according to Harris and Benedict, that there is no differentiation of sex in total metabolism.

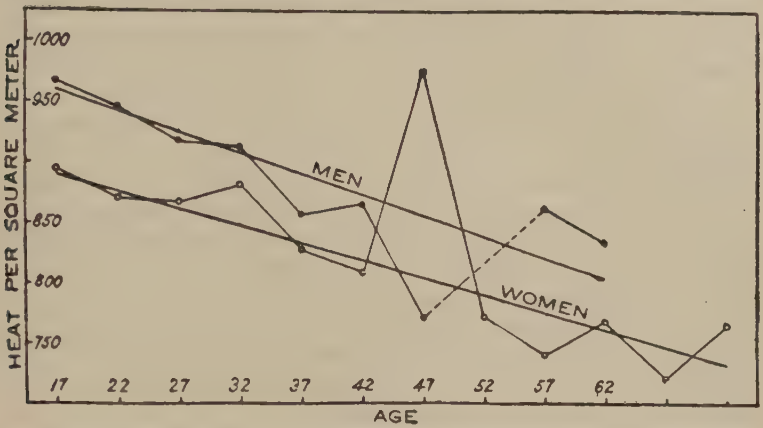

FIG. 204.—Mean daily basal metabolism per square meter of body surface for men and women classified according to age. (Harris and Benedict, Carn. Inst. Publ. #279, Wash., D. C., 1919, Diagram #22, p. 120.)

ENERGY METABOLISM OF THE INFANT

Metabolism Before Birth.—Differences in Metabolism Between Growing and Mature Cells.—It is already clear that the chemical processes by which the living substance is maintained are not identical with those by which it is originally produced. We know, for example, that growth and division of the nuclei are essential in the production of new tissues, while the mere replenishment of cell materials, such as is taking place continually on a small scale or such as may take place in convalescence on a large scale, may go on without division of the nucleus. Since it is known that the nucleus is essential to processes of intracellular digestion,[197] it is possible that the nucleus plays some essential rôle in this process of replenishment; but the fact that the nucleus itself does not grow and divide under these circumstances,[101] together with the fact that its reactions and constitution are known to be different from those of the cytoplasm, makes it very probable that growth involves chemical processes not concerned in the replenishment which follows ordinary waste or that which follows extraordinary waste in diseased conditions. Rubner[159] has drawn attention to the fact that the maintenance tendency is of primary importance even in the young organism, since the "wear and tear" quota (Abnutzungsquote) must be satisfied before growth (post-embryonic) of the organism as a whole can assert itself. If we assume that the every-day repair concerns mainly the cytoplasm, except where cells are actually being destroyed, Rubner's view might be interpreted to mean that the processes in the nucleus which result in its growth and division can take place, even in the young organism, only under certain optimum nutritive conditions of the cytoplasm.

There is no reason for thinking that the mechanism by which energy is liberated in young cells is different from that which performs the same service in mature cells. The living substance of all cells (with the exception of the anaerobic forms) is dependent upon some power, call it the "activation of oxygen," whereby oxygen becomes capable of uniting with the elements of the soluble foodstuffs at a temperature much below the ordinary kindling temperature. We need not delay to discuss more than one of the different theories which have been advanced to account for this "activation."

Warburg's[200] observation that fertilized sea urchin eggs absorb six to seven times as much oxygen in the same length of time as do unfertilized eggs, lends weight to the view that oxygen is in some way essential to the growth process, but his further observation that there was no proportion between the amount of oxygen absorbed and the number of nuclei (blastomeres) present, and that still more oxygen was absorbed when the eggs were placed in hypertonic solutions and cell divisions had ceased,[201] certainly do not favor the idea that oxygen absorption is dependent upon nuclear activity. This is in accordance with Rubner's[161] view that the morphological changes in the nucleus accompanying cell division are the expression of synthetic processes rather than of the destructive processes of oxidation.

Warburg's View as to the Significance of Oxidation.—Bayliss[9] explains the chemical process of oxidation in the cell as follows: "Some autoxidizable substance in the cell takes up molecular oxygen, with the formation of peroxides and activation of half the oxygen. The other half of the oxygen serves for *complete* oxidation of part of the autoxidizable substance. These peroxides are acted upon by peroxidase, with further increase of active oxygen, which is able to bring about oxidation of substances not autoxidizable and otherwise difficult of oxidation." The *structure* of the cell, however, also plays a part. For example, according to Warburg,[202] in a muscle cell a much larger part of the chemical energy appears as free energy than if the cell is disintegrated. The arrangements within the cell which we call cell structure "in some way catch the chemical energy of the oxidation processes before it has fallen to the state of free heat." It is by such arrangements or structure that the work of a contracting, a secreting, an absorbing cell, etc., is carried on.

Even in cells which do no external work or osmotic work, however, structure is important for oxidation. Thus, in the unfertilized eggs of the sea urchin, Warburg and Meyerhof have shown that the addition of iron salts increases oxidation very perceptibly. Salts of no other metal do this. Iron, in other words, is a catalyst for oxidation. Now the significance of structure, (alveolar, if we please), as Warburg sees it, is just this, that it affords surfaces for the condensation of the catalyst and thereby puts it to work.

But why should energy be set free in cells that do no work? Warburg's answer to this is that the liberation of energy by oxidation preserves the structure, or the integrity, if one will, of the living substance. If cell constituents are to be prevented from mixing freely, diffusion surfaces must be maintained, and the maintenance of their semipermeable properties calls for a certain difference of electric charges which can only be kept up by the liberation of energy from some source. Hence it is that all living substance must respire and must liberate a certain amount of free heat. The maintenance of a constant temperature would, on this view of the matter, be a fundamental property for cells whose *structure* could be maintained only by a certain rate of energy release (p. 522).

Metabolism of the Embryo.[122]—Whatever be the explanation from the standpoint of the individual cell, there is no doubt that development, in the embryonic stages at least, does occasion a more active production of carbon dioxide per unit of mass than takes place in adult tissues. This has been demonstrated by Farkas for the eggs of the silkworm, by Bohr for the embryo snake, by Bohr and Hasselbalch, and by Hasselbalch alone for the developing chick, and by Bohr for the embryo guinea pig. That this greater evolution of carbon dioxide is the expression of a greater liberation of energy also is rendered perfectly certain by the calorimetric measurements made by Farkas of the heat of combustion of unincubated and incubated silkworm eggs and those of Tangl on the eggs of the cadaver fly; by similar measurements made by Tangl and by Tangl and Mituch on unincubated and incubated hen's eggs; and by the direct calorimetric determination of the heat produced in the developing hen's eggs made by Bohr and Hasselbalch.[32]

Bohr and Hasselbalch found on the fifth day of incubation of the hen's egg a production of CO_2 amounting to 2,000 c.c. per kg. of embryo per hour as against 718 c.c. per kg. and hour for the adult hen (Regnault and Rieset). The CO_2 production from the eighth to the twenty-first day (end), of incubation was only a little greater in the embryo than in the adult hen, but was sufficiently high for the authors to feel justified in concluding that it was "a condition for the organization of the new tissue and not alone for the maintenance of tissues already formed." Grafe,[66] in reviewing this work, lays special emphasis on the fact that the highest energy production takes place at a time when the work of differentiation is most active. Bohr had previously supported this view with the evidence derived from his study of embryo snakes.[31]

Increasing the temperature from 15 to 27°C. increased the CO_2 output of an embryo weighing 3.8 gm. about 2.8 times, while the same increase in temperature raised the output of an embryo weighting 0.5 gm. exactly four times. The greater increase produced in the younger embryo, Bohr believes, was due to the greater change in the intensity of the developmental processes. That is, the processes of new formation (differentiation) are more active in the younger stage and it is this part of the developmental processes which is responsible for the more active metabolism.

Tangl's results on the hen's eggs indicate an average heat production for the entire incubation period of 100 calories per kg. per day as against 71 calories per kg. per day (at 18 to 20°) for the adult hen found by E. Voit,[199] an increase of 41.3 per cent. Tangl concludes that the energy required for development (Entwickelungsarbeit) is considerably greater than that required for mere maintenance of the adult organism (Erhaltungsarbeit). The difference he designates as Bildungsarbeit.[190] Bohr's findings on the pregnant guinea pig are not so convincing. The average production of CO_2 in the embryo* he found to be 509 c.c. per kg. and hour; that of the mother 462 c.c. per kg. and hour—an increase of only 10 per cent. Granted that the conditions of heat loss were the same in the two, which is doubtful, the amount of metabolism which could be ascribed to any developmental process as opposed to the maintenance processes would be very small.

Rubner[161] believes that the law of surface area is applicable to the embryo. He calculates that the metabolism of the newborn mammal, assuming its weight to be 8 per cent. of its mother, would be nearly double as much per kilogram and hour as that of the mother.†

Because the embryo is less active in every way than the newborn, its metabolism per unit of weight should be considerably less than this, which indeed the results of Bohr and Tangl show to be the case. Rubner explains the higher metabolism of the embryo per unit of weight, therefore, as due not to any specific requirement for developmental energy, but entirely to the greater loss of heat by the relatively greater surface. He is obliged, however, to eliminate the first four-tenths of the embryonic life from the operation of this law, because within that period the embryo is of no appreciable size as compared with the mother. On the basis of the average composition of living substance in mammals and using seven-tenths of the metabolism of the newborn as the rate for the embryo, Rubner calculates that for the remaining six-tenths of the gestation period the "growth quota" of the embryo in most mammals is from 38 to 40 per cent. of the energy supplied, as compared with 34 per cent. for extra-uterine life. In other words, for each calorie of heat value stored in the newborn, nearly two calories of energy must be expended, while for each calorie deposited in the embryo only one and one-half calories need be expended (on the basis of 40 per cent.). We shall see that the higher metabolism of the embryo and fetus is continuous with that of the newborn.

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* Estimated by noting the difference in the output of the mother, under anesthesia and immersed in a warm bath, when the umbilicus of a single embryo was clamped off.

† From some unpublished experiments on individual newborn pups, performed some years ago, the writer is able to confirm this prediction approximately.

Respiratory Quotient of the Embryo.[122]—The qualitative differences in the metabolism of the embryo from that of the adult depend on the kind of food material supplied by the mother in the egg (oviparous development) or by the circulation (viviparous) for the nutrition of the embryo. A hen's egg contains no carbohydrate; hence the respiratory quotient in development of the chick can never be greater than 0.78 (pp. 534 and 574). The chemical studies of Liebermann, the calorimetric determinations of the heat of combustion by Tangl and the metabolism studies (using both the direct and the indirect methods) by Bohr and Hasselbalch all agree in showing that the material oxidized in the development of the chick is fat. Liebermann believed that some nitrogen was lost, but both Hasselbalch and Tangl and Mituch have shown that this is incorrect. The nitrogenous building material is not used as a source of energy.

The source of energy for the silkworm embryo, according to the chemical studies of Tichomiroff and the respiration experiments of Farkas; for the blow-fly embryo according to the respiration experiments of Weinland; and for the cadaver fly according to the calorimetric determination of Tangl is likewise mainly fat. No nitrogen is lost in gaseous form during the development of any of these insects, but a portion of the energy (according to Farkas approximately one-third) arises from the oxidation of proteins to uric acid. Both Tichomiroff for the silkworm egg and Weinland for the blow-fly recorded a reduction of the glycogen content of the egg, but Weinland believes this may have been converted to chitin. There is no evidence, he says, that glycogen has served as a source of energy.

Our information as to what material is the source of energy for the mammalian embryo is extremely scanty. Cohnstein and Zuntz analyzed the blood in the unbilical artery and vein of the sheep embryo for oxygen and carbon dioxide, and noted a difference of 4.67 vols. per cent. O_2 and 4.72 vols. per cent. CO_2, in one case and 4.0 vols. per cent. O_2 and 6.5 vols. per cent. CO_2 in another. These figures would give respiratory quotients of 1.01 and 1.6 respectively, for the two embryos. It is doubtful whether these figures are to be trusted, since on the basis of the same analyses the authors claim a metabolism for the embryo of only one-fourth to one-sixth as much per unit of weight as for the mother. The quotients agree, however, with those found by Bohr on the embryo of the guinea pig. Bohr took the difference between the exchange of the pregnant animal (after operation under total gaseous anesthesia and immersed in a warm bath) before and after clamping off a single umbilicus. The respiratory quotient indicated for the embryo was always in the neighborhood of unity. Oddi and Vicarelli report also a progressive increase in the respiratory quotient in the course of pregnancy in the mouse. According to these observations, therefore, the most diffusible of the foodstuffs, the one most readily passed through the placenta, is probably the source of energy for the mammalian embryo. There is no satisfactory evidence as yet that proteins participate to any considerable extent in furnishing such energy.

We shall see that the R. Q. of the newborn infant is to be explained from the standpoint of the abundance of diffusible materials reaching the fetal circulation during birth.

Energy Metabolism Immediately Before Birth.—The metabolism of the fetus immediately before birth has not been determined independently, but only in connection with that of the expectant mother. It is proper to inquire in this connection, however, what share of the extra metabolism of pregnancy is borne by the fetus, and particularly whether the extra metabolism is proportional to the number or the weight of the newborn. New points of view may also be gained regarding the relation of postpartum metabolism of mother and child to antepartum metabolism of mother and fetus.

With the dog, Murlin[122] was able to show that the extra heat production of mother and offspring just before parturition was very nearly proportional to the weight of newborn pups delivered three days later. It was impossible to record the metabolism nearer to parturition than this on account of the restlessness of the dog. Quite fortunately it happened that the same dog gave two litters, one consisting of a single pup, the other of five pups. Comparing the total metabolism on the third day before parturition in the two pregnancies with that of the dog in sexual rest after lactation had been stopped, it was found that the extra energy metabolism at the culmination of pregnancy for the one pup was (551.3 − 505.3 =) 46 calories or 164 calories per kilogram of the single newborn pup; and (763.8 − 505.3 =) 258.5 calories or 165 calories per kg. for the five newborn pups. In other words, the extra metabolism was very nearly proportional to the weight of the newborn.

46 cal.:258.5 cal.::280 gm.:1,560 gm.

It should be emphasized that the temperature of the cage was the same on the several days compared, that the mother dog was trained to lie perfectly still, and finally that the diet was exactly the same in weight and composition on all these days.

It is interesting to observe that the extra metabolism necessary to maintain the embryo (and all accessory structures of the mother's body) at a time when the pregnancy is at its highest phase is very nearly equal to the amount which the newborn of the same weight would theoretically produce (according to the law of surface), the first day after delivery, if exposed to ordinary room temperature and if resting. Taking the curve which Rubner gives, on the basis of Hensen's figures, as representing the rate of growth of the guinea pig embryo in a gestation period of almost the same length as that of the dog (67 instead of 63 days),[161] we may calculate that the single pup which weighed 280 gm. at birth would have weighed 240 gm. three days before birth, and the average weight of the five pups (320

Table 4.—Energy Metabolism before and after Parturition Compared with Sexual Rest. Results Calculated for 24 Hours

Day from parturition	Weight in kilogram	Temperature of cage	Calories, total energy			Calories, energy per kilogram	
			In food	Produced	Retained	In food	Produced
First pregnancy							
Third before (June 23)......	14.5	28.0°C.	907.4	551.3	356.1	62.5	38.0
Parturition (June 26).......		One pup born: weight, 280 gm.					
Sexual rest, after lactation							
Three weeks after parturition (July 15)................	13.78	28.1°C.	907.4	505.3	40.21	66.5	35.9
Second pregnancy							
Third before (Dec. 11)......	16.86	27.1°C.	907.4	763.8	143.6	53.8	45.8
Parturition (Dec. 14).......		Five pups born: weight 1560 gm.					

gm. at birth) would have been 280 gm. three days before. Using Meeh's formula and Rubner's average figure for the metabolism of the dog per square meter of surface, the metabolism of the single pup at 240 gm. would be $11.2\sqrt[3]{(240)^2} \times 0.1050 = 45.4$ calories and of the average pup of the five at 280 gm. $11.2\sqrt[3]{(280)^2} \times 0.1050 = 50.33$ calories. Thus:

		Calories
Extra metabolism of a dog pregnant with a pup of..........	240 gm. =	46.0
Theoretical metabolism of a pup of 240 gm. at rest and at room temperature....................................		45.4
Extra metabolism of a dog pregnant with five pups weighing (5 × 280)..	1400 gm. =	258.5
Theoretical metabolism of five pups weighing 280 gm. each at rest and at room temperature.........................	=	251.6

If this law of surface area is applicable to the embryo and the newborn, as Rubner believes it is, we may conclude that the metabolism of the uterus, mammæ, etc., would exactly compensate for the difference between the metabolism of the newborn at room temperature and the metabolism of the embryo at the temperature of the mother's body. In other words, the curve of total metabolism of mother and offspring would scarcely suffer any interruption at birth, if mother and offspring after birth could be kept sufficiently quiet for the demonstration. If this generalization should be true of the human mother and her offspring it would be a matter of considerable interest and importance.

To secure proper conditions for this inquiry, the problem was taken to the Nutrition Laboratory of the Carnegie Institution in Boston, where a bed calorimeter had been perfected large enough to contain the mother and child. Three subjects were studied.[38] The metabolism of the pregnant woman was determined a number of times throughout the last two or three weeks, and similar determinations were made upon the mother and child as well as upon the mother alone after parturition. A table showing the comparative results is given below.

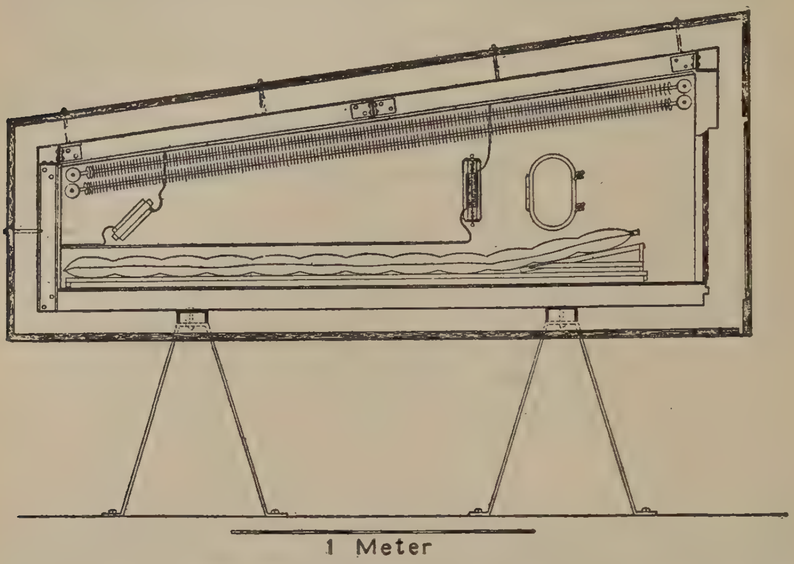

Fig. 205.—Cross section of bed calorimeter. (Benedict and Carpenter, Carn. Inst. Publ. No. 123, Wash., D. C., 1910, Fig. 26, p. 46.)

Table 5.—Energy Metabolism of Mother and Child Together before and after Parturition

Case Mean of all days before and after delivery	Respiratory exchange				Energy production, Calories per hour			
	Average body temperature, Degrees Centigrade	CO_2 gm. per hour.	O_2 gm. per hour	R. Q.	*a*—Direct	*b*—Indirect	$\frac{a+b}{2}$	Per cent. difference
Case 1.								
1st, 4th, and 6th days before delivery	36.75	21.3	18.4	0.85	60.0	61.3	60.7	
2d, 5th, 12th, 14th and 17th after delivery	36.9	20.2	18.5	0.80	61.2	61.2	61.2	+0.87
Case 2.								
13th, 17th, 19th, 20th, and 22nd before delivery	36.68	22.3	19.6	0.83	63.6	65.9	64.7	
2d, 5th, and 11th after delivery	36.8	21.7	20.4	0.78	71.1	67.5	69.3	+7.1
Case 3.								
1st, 3d, 17th, 21st, and 24th before delivery	36.64	23.9	20.2	0.86	72.2	68.7	70.6	
4th, 8th, and 11th after delivery	37.23	23.1	20.3	0.81	70.8	68.6	69.7	−0.9

The energy production expressed in absolute figures in both cases 1 and 3 is the same after as before parturition. In case 2 there was an increase of about 7 per cent. in the postpartum over the antepartum metabolism. This can be accounted for by the fact that the child cried lustily at times on two out of three postpartum days and the crying disturbed the mother. One is justified, therefore, in the conclusion that the total metabolism of mother and child immediately after birth of the child is not greater in absolute amount than it was immediately before delivery. The extra metabolism of pregnancy, at its culmination, due in part to the activity of the accessory maternal structures as well as to the fetus, as in the dog, is just compensated by an extra metabolism set up in the newborn as it begins an independent existence.

It is certain from these experiments that the newborn child sets out upon its career under a stimulus which causes its metabolism to be augmented very materially. How the metabolism is further accelerated within the first few weeks of life we shall see later.

Energy Metabolism of the Newborn.—Because of its practical importance, this topic must be prefaced with a discussion of the methods employed in the study of infant metabolism.

Four methods have been chiefly employed in the observations upon newborn infants: one of them German in origin, the other three French. The German method is that of Pettenkofer and Voit (p. 533) with a smaller chamber and adapted in other ways for use with an infant. It has been employed with the newborn by Birk and Edelstein[28] and by Rubner and Langstein.[165] For use with an infant the chamber may be warmed artifically or the infant may be protected by clothing. The chamber is ventilated with a generous current of air and the carbon dioxide given off by the subject is found by subtracting the CO_2 content of the ingoing air from that of the outgoing air. Naturally the entire volume of air is not analyzed, but only aliquot samples continuously taken. The heat production by this method is based upon the carbon dixoide production. Water is absorbed from ingoing and outgoing air in sulphuric acid and pumice stone. In the hands of skillful investigators the method has given useful information especially as regards water elimination, but it is open to two main objections: namely, that it is difficult to employ short periods, and the determination of oxygen absorption is not possible.

The first French method is that originally devised by Regnault and Rieset[145] in 1849. It consists essentially of an air-tight chamber in which the subject is confined, and of devices for supplying oxygen as rapidly as it is absorbed, and for taking up the CO_2 as rapidly as it is produced. In its original form oxygen was supplied by displacement of water under very moderate pressure from flasks, and the CO_2 was absorbed in liquid alkali. In later modifications oxygen is supplied from a high pressure bomb or tank, the pressure being suitably reduced by a valve and ingress of the gas regulated by some automatic device. Carbon dioxide is absorbed in all modern constructions by soda lime.

The method of Regnault and Rieset is known as the closed-circuit method, as opposed to the open-circuit method of Pettenkofer and Voit. The entire circuit consisting of chamber and absorbers must be air-tight and the air is kept in motion by a positive blower, its deficiency in oxygen being made up by admission of the gas from outside as the CO_2 is combined chemically with the soda lime and thereby withdrawn. This type of ventilation was adapted to the calorimeter of Atwater and Rosa, originally built for the open-circuit type, by Atwater and Benedict.[3] A small calorimeter of this type for the study of the metabolism of infants was erected at Cornell University Medical College by H. B. Williams in 1910. Experiments with this apparatus upon babies by Howland[86] having demonstrated that the metabolism as directly measured in the form of heat differed from the metabolism calculated (indirect method) by only a very small amount, this apparatus has remained the only one of its kind to date, other constructions depending upon the indirect method only.

The essential features of a respiration apparatus for determination of the energy metabolism by the indirect method are: (1) Some means of maintaining a constant temperature and of varying the same at will; (2) some means of recording the muscular activity of the subject, also the pulse and respiration at will, and (3) a method of determining the residual analyses of the air at the end of each period. An apparatus constructed in the Massachusetts General Hospital by the Nutrition Laboratory of the Carnegie Institution fulfills these requirements in the main, and has been used in an extended series of observations on newborn and older infants by Benedict and Talbot.[22,21,23]

Benedict Apparatus.—This apparatus was originally described by the authors[20] in a preliminary publication in 1912. Later it was somewhat modified and was employed in most of the observations in the form shown in Fig. 206. In this form it was capable of determining the oxygen directly on exactly the same principle as that described above for the respiration calorimeter.

The chamber, *C*, in which the infant reposes, is provided with a water jacket, *WW* for temperature control. The air leaves the chamber near the right-hand end at *O*, and is drawn by the rotary pump over a wet- and dry-bulb thermometer, *Z*, which gives the amount of moisture in the air of the chamber. A can, *N*, filled with dry cotton batting is also placed in the air-current between the blower and the chamber to act as a muffler. After leaving the exhaust side of the blower, *P*, the air is forced through an empty glass bottle, *A*, which serves as a trap should any back-pressure take place and sulphuric acid be forced back from the water-absorbing vessels *B* and *C*. These latter vessels are of peculiar construction. They were designed by Williams[206] for the small respiration calorimeter at Cornell. The air passes along a pipe to a two-way valve, V_1, where it may be deflected through either of the soda-lime bottles D_1 or D_2 in which the carbon dioxide is absorbed. Since the reagent must be somewhat moist to facilitate the absorption it gives up water-vapor to the dry air-current, which must in time be absorbed by sulphuric acid in the Williams bottles E_1 or E_2. The air next passes through the two-way valve, V_2, and enters a small can, *F*, which contains dry sodium bicarbonate, where the unweighable and nearly imperceptible sulphuric acid odors are effectually removed. The air then returns to the chamber through the by-pass, *J*, or, if it is desired to moisten the air, the current can be deflected by closing the valve, *R*, in the by-pass, *J*, so as to pass all of the air through distilled water in the Williams bottle, *K*. The air is now free from carbon dioxide and contains the water-vapor added in passing through *K*, but is still deficient in oxygen. This deficiency is made up by admitting oxygen from the pressure cylinder, *L*. The air thus enters the respiration chamber, *I*, somewhat moist and with approximately the normal percentage of oxygen.

Either series of absorbers may be used as desired, for if the air current has been passing through the series D_1 and E_1 for a given experimental period, the air can be instantly deflected through the series D_2 and E_2 by turning the valves V_1 and V_2. These valves are connected by a long rod so that they may be thrown simultaneously by one movement of the hand.

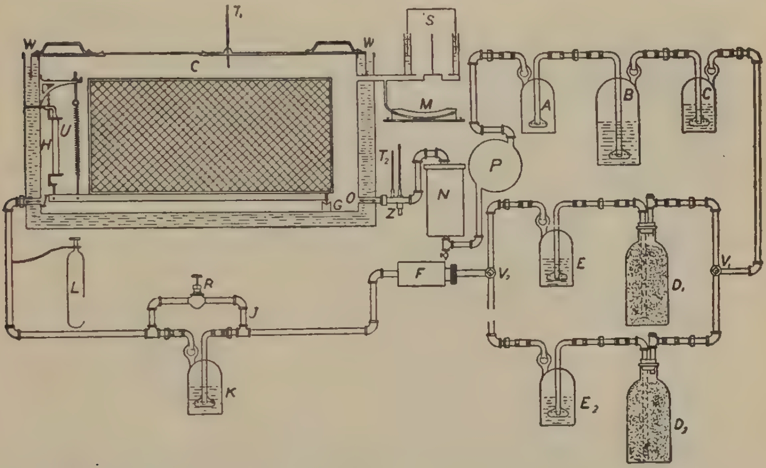

FIG. 206.—Detailed scheme of respiration apparatus for infants. (Benedict and Talbot.) *C*, chamber; *W*, *W*, water jacket; *O*, outgoing air-pipe; *Z*, psychrometer; *N*, muffler; *P*, blower; *A*, acid trap; *B* and *C*, Williams water-absorbers; V_1 and V_2, 2-way valves; D_1 and D_2, carbon-dioxide absorbers; E_1 and E_2, air-dryers; *F*, sodium bicarbonate can; *J*, by-pass; *R*, valve; *K*, air moistener; *L*, oxygen cylinder; *I*, ingoing air-pipe; *S*, spirometer; T_1 and T_2, thermometers; *M*, manometer; *U*, spiral spring; *H*, pneumograph. (Carn. Inst. Publ. No. 201, Wash., D. C., 1914, Fig. 2, p. 35.)

Since the air-current is entirely closed a small spirometer, *S*, is attached at the upper right-hand corner of the respiration chamber, thus providing for an expansion or contraction of the air. A thermometer, *T*, in the cover of the chamber and a second thermometer, T_2, in the outgoing air serve to indicate the temperature changes, while the manometer, *M*, shown below the spirometer indicates the pressure of the air in the chamber.

By noting the increase in weight of the absorbers, D_1 and E_1 or D_2 and E_2, the amount of CO_2 absorbed is known. It is possible that the amount of water vapor given up by D_1 or D_2 to the dry air passing through it may be actually more than the amount of carbon dioxide absorbed, or that the bottle, D_1 or D_2, may be losing weight; on the contrary, the water-vapor given up is immediately absorbed by, *E*, and hence the algebraic sum of the difference in weight of the two bottles gives the weight of the carbon dioxide absorbed. Usually both bottles are weighed on a balance at the same time. The loss in weight of the cylinder, *L*, gives the amount of oxygen absorbed by the subject, corrections being made for any variations in temperature and barometric pressure. Corrections for changes in composition of air inside the chamber may be made by withdrawing samples through a by-pass not shown in the figure.

The infant is placed inside a wire crib supported at one end upon a stout spiral spring, *U*, and at the other end upon a knife edge, *G*; this mode of suspension affords a means of recording the muscular activity of the infant. Alongside the spring, *U*, is a pneumograph, *H*, the distention or contraction of which compresses the air inside of the pneumograph tube, thus transmitting to a delicate tambour outside a record of the lightest motion of the cage. This method is more fully described later on p. 625.

The respiration chamber is constructed of galvanized iron or copper, and is 77 cm. long, 25 cm. deep, and 37 cm. wide. To insure temperature control, the whole respiration chamber is surrounded by a water jacket consisting of a second shell of galvanized iron or copper with a space of 5 cm. between the two walls. The water jacket which is filled with water to within a few centimeters of the top acts also as a seal when the cover is placed upon the apparatus. In the cover are a window securely fastened and an opening for the air thermometer.

The psychrometer is essential for indicating the degree of moisture inside the respiration chamber. This is of value not only for the comfort of the infant, but also for computing the amount of oxygen inside the chamber at the end of the experimental period. Experiments carried out with a very delicate instrument have shown that the depression of the wet-bulb thermometer can be measured with great accuracy and the amount of water-vapor in the air computed with an exactness sufficient for all practical purposes. The two thermometers are graduated in 0.1°C. and are capable of being read with a lens to 0.01°C. It is necessary to make sure that the cloth around the wet-bulb thermometer is kept thoroughly drenched with distilled water, also that the capillarity of the fiber is good as otherwise the cloth may become partially dried and inaccurate results obtained. Prior to each experiment the wet bulb is drenched by using an elongated medicine dropper filled with distilled water.

The blower, *P*, is connected with a leather belt to a small electric motor and can be provided with a safety clutch to prevent reversing the wheel through carelessness, and the drawing over of sulphuric from the water absorbers. The safety trap, *A*, is an additional security against this mishap. The blower used with this apparatus gives a ventilation of about 35 litres of air per minute when rotating at a speed of 270 r.p.m. Experiment with an alcohol flame shows that this rate of ventilation does not produce a draft which would be perceptible by the infant. The fact that the relative humidity does not become unduly low, even without use of the water bottle *K*, is proof that the infant is sojourning in an atmosphere approximately normal.

To remove the moisture coming from the lungs and skin of the infant, and any additional moisture from water bottle *K*, one large-sized Williams bottle, *B*, is usually sufficient. However, a second bottle, *C*, removes the last traces of water-vapor. To facilitate the handling of these bottles in weighing and to prevent breakage, they are usually enclosed in a small wire basket with a handle by means of which they may be suspended directly from a hook on the arm of the balance.

The Williams bottles as well as the soda-lime bottles are fitted with short lengths of rubber tubing of good quality to which are attached respectively male and female parts of ordinary garden hose couplings of standard three-fourth inch size; with a standard rubber hose gasket, the couplings are made air-tight by a single twist of the hand.

For infants weighing not less than 3 to 5 kg. the soda-lime container holding in the neighborhood of 2 kg. soda-lime is capable of absorbing all the carbon dioxide. This amount of soda-lime will take up as much as 75 gm. CO_2 without renewal.

The direct determination of oxygen may be made either by weighing the small cylinder of gas, *L*, and noting its loss in weight during the experiment, or by passing the gas, under reduced pressure, through a delicate and accurate gas meter. The volume of air inside the respiration chamber is about 75 liters. Correction for temperature change is therefore necessary in order to determine the actual volume of air at the end of every experimental period. Two carefully calibrated mercury thermometers, one in the cover of the chamber, the other the dry-bulb thermometer of the psychrometer, are used to record such changes. While the two thermometers rarely read alike, their fluctuations are usually parallel. The average of the readings of the two is taken as representing the average temperature of the air in the chamber.

It is important that the respiration chamber shall not be subjected to sudden fluctuations of temperature during the experimental periods. The water jacket serves to damp any changes in the room temperature, and by supplying either heat or cold to maintain the chamber at a temperature either above or below that of the room. During cold weather a mercury thermo-regulator placed in the water and connected with a small burner placed underneath, secures a constant temperature which may be regulated at any desired level. In the excessively warm days of summer, it is necessary to place ice in the water tank.

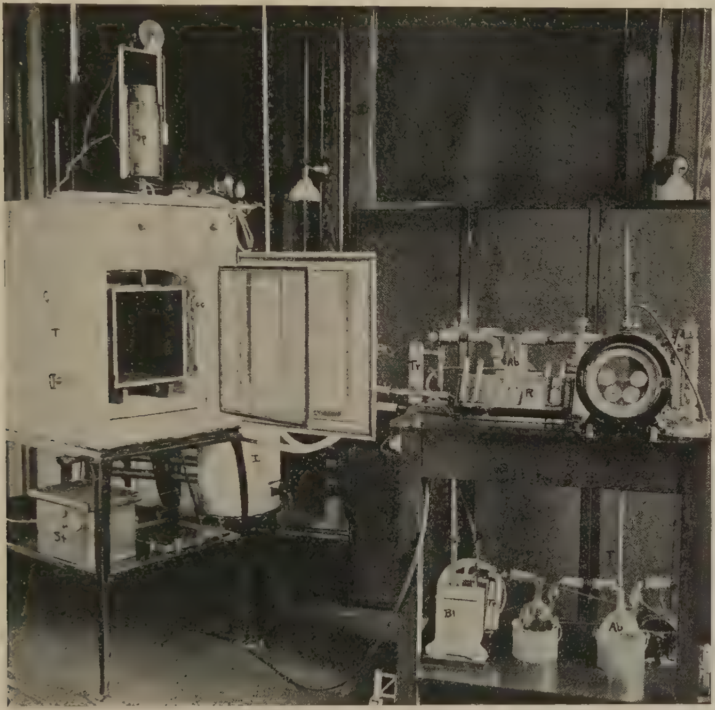

Fig. 207.—Respiration apparatus for infants. (Murlin.) Sp, spirometer; T, thermometers; O, oxygen cylinder; R, residual system; Tr, traps; Bl, blower; Ab, absorbers; St, storage battery; I, ice tank; p, pipe from blower to residual system; cc, cooling coil. (Original.)

An apparatus devised by the writer[125] and constructed for use in Bellevue Hospital, New York, follows the same general principles as that just described, but employs as a means of controlling the temperature the electrically heated and regulated incubator of Freas.[60] For this reason it has been described as a "respiration incubator" and can be used as an incubator for premature infants independently of its features as a metabolism machine.

Description of Author's Apparatus.—The regular plan of construction of the Freas air thermostat was departed from in a few particulars. For example, it was necessary to have a considerable number of openings through the wall for the passage of the ventilating pipes and cooling-coil, the introduction of thermometers, the connection of the oxygen regulator, etc. The range of temperature was fixed at from 20 to 50°C., the capacity of the heater being limited to 200 watts. The glass doors were made as large as the front end, thus permitting plenty of light to enter, and were provided with strips of felt so as to make the closure practically air-tight.

The Respiration Chamber.—The chamber shown inside the incubator measures 30 by 32 by 76 cm. inside. It was made of 14-ounce tinned copper, strongly lock-jointed and soldered, and was rimmed at the front end by a heavy brass casting. Another casting of the same dimensions was made as a frame for the glass head or door of the chamber (seen on the shelf in Fig. 207). The glass is held in place by litharge cement covered with heavy wax and a coat of white lead. A heavy rubber gasket is cemented to the brass rim, and a perfectly air-tight closure of the chamber is secured by clamping the frame of the head firmly against this gasket by means of 12 L-shaped steel bolts, which engage the back side of the brass rim. The chamber is mounted on wooden runners and is strongly reinforced by means of three galvanized iron ribs girthing it at equal intervals from front to back. Pressure changes inside or outside the chamber, therefore, do not alter its volume. Since the incubator measures 46 by 48 by 100 cm. inside, a space 7.5 cm. wide is left on all sides of the chamber.

Ventilation and Measurement of Respiratory Exchange.—The ventilation of the respiration chamber is accomplished by means of a Benedict "universal respiration apparatus,"[11] connected to it by means of wide rubber tubing and one-half inch brass pipes. The brass pipes are screwed into strong brass bushings soldered to the copper wall. The inlet pipe enters at the upper back corner of the chamber on the right side and the outlet is connected with the lower front corner on the left (Fig. 207). Thermometers* are admitted to the inlet and outlet pipes by means of T-joints.

The Absorber System.—The Benedict apparatus was so constructed that two sets of absorbers could be connected at once and the change from one set to another is accomplished with a single lever operating both valves. Each set of absorbers consists of two soda-lime jars for absorption of carbon dioxide and a sulphuric acid absorber for catching the water lost from the soda lime. Each of these absorbers is small enough to be weighed (separately) on a balance sensitive to 0.001 gm. The soda-lime absorbers are made on the plan adopted for the absorbers used with the Sage calorimeter in Bellevue Hospital.[147] The sulphuric acid absorber is the gas washing bottle designed by Williams.[206] Immediately following the sulphuric acid absorber is a brass tower (Fig. 207) containing sponges kept moist with very dilute sodium hydroxid solution, which serves the double purpose of imparting a slight amount of moisture to the air and of arresting any traces of acid fumes which may come from the drying bottle.

Since the water given off from the lungs of the child does not enter into the computation of the heat production by the indirect method (except as this water may affect the volume of the oxygen admitted), the absorbers used in the collection of this water are not weighed. They consist of two Williams bottles placed in series after the blower on the under part of the absorber table. A brass trap, of a capacity about equal to the amount of the sulphuric acid contained in the first Williams bottle, is introduced for the safety of the blower. A bicycle coaster brake on the large pulley of the blower makes it impossible to turn the blower the wrong way; but the trap would catch any acid which might be drawn back by sudden blockade of the air-circuit at any point.

The Residual System.—The measurement of the oxygen absorbed by the child is based on the general proposition that oxygen be admitted to the air-circuit just as rapidly as it is used. This presupposes that the respiratory products should be absorbed and removed from the air as rapidly as they are produced. The efficiency of the absorbers is such that as far as the welfare of the child is concerned the ventilation is perfect. Neither carbon dioxide nor water-vapor can accumulate to any appreciable extent. But an *absolutely* perfect adjustment of the rate of ventilation so as to leave the composition of the air *exactly* the same at the end of a period as at the beginning is impossible, especially if the child should cry or void urine near the end of the period. Since the admission of oxygen is regulated by the total volume of the air (see below) and since this volume will vary with the amount of water in it as well as with the temperature and barometric pressure, it is necessary to know the composition of the air at the close as well as at the beginning of a period. The analysis is carried out by diverting a measured sample of air from the main circuit, causing it to flow through a special set of absorbers and returning it to the system without loss of anything more than the small quantities of carbon dioxid and water contained in it. These analyses are called the residuals because they give information as to amounts of the various gases *residual* in the air at definite moments.

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* More recently electrical resistance thermometers have been introduced for reading the temperature of the air.

A small copper pipe, *p*, is tapped into the main circuit on the positive side of the blower and is led upward through the top of the table. By turning a stop-cock at the base of this pipe a small fraction of the total air-current can be drawn off. The residual absorbers[15] consisting of three U-tubes (Fig. 207, *R*) (the first containing sulphuric acid and pumice stone, the second finely granular soda lime, and the third sulphuric acid and pumice stone again) are connected to this small pipe and the air having passed through them is conveyed to the meter where it is measured, thence through a drying-tower (the meter contains water) and back to a point in the main system where the pressure is low.

The U-tubes are weighed to the fourth decimal place before and after drawing off the sample. When the amounts of water-vapor and carbon dioxid in this measured sample (usually five liters) are known, the total amounts in the entire system are readily calculated. By a series of corrections which will be better understood after the method of conducting an alcohol check is explained, the amount of oxygen residual in the air at the time the air sample is taken can also be computed.

The Oxygen System.—Oxygen is admitted into the ingoing air so that it may be thoroughly diffused into the chamber. The amount admitted is regulated by the method first described by Benedict and Carpenter[15] and as slightly modified by Williams[206] in his construction of the baby calorimeter. The essential parts of this arrangement consist of a spirometer, *Sp*, which serves as a tension equalizer and volume indicator at the same time (Fig. 207), and a magnet, *Mg*, which, when actuated, releases pressure on a rubber tube leading from the oxygen cylinder (O_2, Fig. 207). The spirometer communicates with a respiration chamber by means of a brass pipe, and a valve in this pipe permits the spirometer to be shut off from the chamber. The oxygen cylinder while in use is suspended from a strong hook at the right side of the apparatus conveniently near the magnet. The magnet is connected through the mercury cups, *Hg*, situated on the horizontal arm above the magnet, with six dry cells enclosed in a box situated on the shelf of the incubator stand. The top or bell of the spirometer is so counterpoised that it responds to very slight changes of tension inside the chamber. The pulley over which the counterpoise weight is balanced carries contact points which dip into the mercury as the bell of the spirometer descends. As the oxygen in the air of the circuit is used up by the child the bell descends until the points make contact with the mercury. This actuates the magnet and releases pressure on the pure gum tubing leading from the oxygen cylinder. Oxygen thereupon enters the circuit until the volume is increased sufficiently to break the electric circuit, when pressure is again applied to the tubing, thereby shutting off the oxygen; and so on.

At the beginning of a period oxygen is let into the system by hand until the pointer on the bell of the spirometer rests at a certain mark on the scale. At the end of the period the system is again filled to exactly the same point. If the volume of air has not changed (by change of temperature, pressure, or composition of the air) the loss in weight of the cylinder would be the amount of oxygen consumed. Such changes, however, would be very exceptional; hence all corrections must be made for every period.

Oxygen cannot be let into the system by any such automatic arrangement until the pressure which exists in the cylinder is reduced to a pressure which the rubber tube will withstand. A valve which reduces this pressure to a few pounds per square inch is a necessary part of the equipment.

The Cooling System.—The walls of the incubator being constructed of materials having a low coefficient of conductivity, the heat produced by the infant would not be conducted away as rapidly as produced, and the temperature inside would rise unless the room air were at a very low temperature. To counteract this tendency and to furnish a chilling effect against which the heater of the incubator should operate, a cooling system was installed. This consists of a coil (Fig. 207, c.c.) of copper pipe, ½-inch inside diameter, making several turns on the two sides and the top of the inner wall of the incubator and carrying a stream of tap-water. At ordinary room temperature and with tap-water coming directly from the mains (that is, not warmed unduly by house pipes), it is not necessary to chill the stream. It flows, however, through a coil of pipe inside an ice-tank (Fig. 207), and in very warm weather the water can easily be kept down to the desired temperature by placing ice in contact with the coil. To secure a constant flow the water is given a constant head of pressure by passing it through a flush tank, operated by a ball-cock, placed near the ceiling of the room. (This tank is too high to be seen in any of the figures, but the pipes leading to and from it are seen.) After passing through the cooling system the water is conducted back to the sink.

A thermometer is placed in the stream of water, and a wheel valve is placed near the tank, so that the cooling effect can be regulated to some extent both by the amount of ice and by the rate of flow of the water. The thermo-regulator of the incubator takes care of the finer regulation. The heater is sufficient to keep the space about the respiration chamber at 27°C., even when the water is at 4°C., and the rate of flow 400 to 600 c.c. per minute. This would be wasteful of electric current, however, and a water temperature of from 10 to 15°C. with a rate of 200 to 300 c.c. of water is more than sufficient to carry away the heat produced by a year-old infant even in very warm weather, unless the infant cries actively. In the latter case the speed of water can be increased, or more ice can be introduced, or the heater can be turned off. With such a cooling effect as just mentioned, the temperature outside the chamber falls very quickly, and within a very few minutes also the temperature inside the chamber.

Heat Control.—If the apparatus is properly constructed it should regulate the temperature in the inner chamber nearly perfectly, as shown in the following example when the subject was a small black dog weighing 4 kg. (Table 6.)

The air temperature rose 0.6 of a degree during this observation and the temperature in the outer air space fluctuated somewhat according as the heat happened to be on or off at the moment of reading; but the temperature inside the inner chamber hardly varied at all during the entire hour.

Control by Combustion of Alcohol.—The accuracy of the entire apparatus may be checked by the combustion of alcohol in the inner chamber and the determination of the "respiratory quotient" of the flame. With the alcohol flame it is scarcely necessary to make corrections for the residual analyses of the air, for if the flame burns uniformly the amount of carbon dioxide found in the air often does not change at all from the beginning to the end of the period. The water almost always falls during the first period, and then remains constant.

TABLE 6.—HEAT CONTROL, SUBJECT, SMALL BLACK DOG

Time p.m.	Thermometer No. 1, ingoing air, degrees	Temperature, thermometer No. 2, between walls, degrees	Thermometer No. 3, inner chamber near center degrees.	Thermometer No. 4, outgoing air, degrees
1:50	23.0	27.0	28.1	27.9
1:55	23.1	27.2	28.1	28.0
2:00	23.2	27.2	28.1	28.1
2:05	23.3	27.3	28.1	28.1
2:10	23.4	27.2	28.1	28.1
2:15	23.5	27.2	28.15	28.1
2:20	23.5	27.1	28.15	28.1
2:25	23.5	27.15	28.15	28.1
2:30	23.5	27.15	28.15	28.1
2:35	23.5	27.1	28.1	28.15
2:40	23.5	27.2	28.1	28.1
2:45	23.6	27.0	28.1	28.1
2:50	23.6	27.0	28.1	28.1

An example of a complete check experiment is given showing the manner of making all corrections. The same corrections and the same methods of calculation are used when the subject is a child.

Dec. 23, 1913. Alcohol check experiment.
Contents of respiration chamber—alcohol lamp and bed.

Vol. of air containing CO_2	67 liters
Vol. of air containing H_2O	66 liters
Vol. of air containing O_2 and N_2	69 liters

First period from 4:52 to 5:52 p. m.

At 4:52 residual analysis.
5 liters air contain 0.0178 gm. CO_2 and 0.0136 gm. H_2O
67 liters air contain 0.238 gm. CO_2 (= 0.121 liter)
66 liters air contain 0.179 gm. H_2O (= 0.223 liter)

To find residual O_2.

Temperature 28.06 C.; barometer 765.1 mm.

log. 69 = 83885 0.121 liter CO_2 + 0.223 liter H_2O = 0.344 liter

$$\log.\ \frac{1}{1 + 0.00367(28.06)} = 95740$$

$$\log.\ \frac{765.1}{760} = \underline{00290}$$

79915 = 62.973 liters at 0° and 760 mm.
less 0.344 liter CO_2 and H_2O
62.629 liters O_2 and N_2
Subtracting four-fifths for N_2 50.1032
12.5258 liters O_2

At 5:52 residual analysis.

5 liters air contain 0.0178 gm. CO_2 and 0.0136 gm. H_2O
67 liters air contain 0.238 gm. CO_2 (0.121 liter)
66 liters air contain 0.129 gm. H_2O (0.223 liter)

To find residual O_2.

Temperature 28.23 C.; barometer 765.3 mm.

$$\log. 69 = 83885$$

$$\log. \frac{1}{1 + 0.00367(28.23)} \quad 95719$$

$$\log. \frac{765.3}{760} = \quad 00302$$

79906 = 62.960 liters at 0° and 760 mm.
less 0.344 liter CO_2 and H_2O
62.616 liters O_2 + N

Subtracting N with which exp'm't started, 50.1032
12.5128 liters O_2

"Respiratory Exchange" Period 1

Gain in weight of CO_2 absorbers	4.850 gm.
Loss in weight of O_2 cylinder.......	5.090 gm.
0.6 per cent. correction for argon =	0.03 gm.
Loss in weight due to oxygen =	5.060 gm.

Residual analyses show: (1) no change in CO_2 of air but (2) amount of O_2 is less. (12.5258 − 12.5128 = .0130 liter = .0186 gm.) This shows that flame used a little more O_2 than was admitted; therefore, 5.060 + 0.0186 = 5.079 gm. O_2 actually used. Reducing weights to volume:

log. weight CO_2 (4.850 gm.) = 68574
log. weight to vol. (CO_2) 70680
39254 = 2.469 liters

log. weight O_2 (5.079) = 70578
log. weight vol. (O_2) = 84496
55074 = 3.554 liters

$$\text{R. Q.} = \frac{\text{Vol. } CO_2}{\text{Vol. } O_2} = \frac{2.469}{3.554} = 0.695$$

Second period from 5:52 to 6:52.

At 6:52 residual analysis.

5 liters air contain 0.0166 gm. CO_2 and 0.0114 gm. H_2O
67 liters air contain 0.222 gm. CO_2 (= 0.113 liter)
66 liters air contain 0.150 gm. H_2O (= 0.187 liter)
0.113 + 0.187 = 0.300 liter CO_2 and H_2O.

Temperature 28.4 C. Barometer 765.3 mm.

$$\log. 69 = 83885$$

$$\log. \frac{1}{1 + 00367(28.4°)} = 95695$$

$$\log. \frac{765.3}{760} = \quad 00,302$$

79,882 = 62.924 liters at 0° and 760 mm.
less 0.300 liter CO_2 and H_2O
62.624 liters O_2 and N

Subtracting N_2 with which exp'm't started 50.1032
12.5208 liters O_2

"Respiratory Exchange" second period.
Gain in weight of CO_2 absorbers 4.968 gm.
Residual analyses show that CO_2 in air was less at 6.52 than at
5.52(0.238 − 0.222 = 0.016) 4.968 gm.
0.016
Actual amount of CO_2 given off = 4.952 gm. = (2.521 liters)
Loss in weight of O_2 cylinder......... 5.500 gm.
Less 0.6 per cent. for argon........... 0.033
5.467 gm.
Residual analyses show more O_2 in air at 6.52 than at 5.52
12.5208 − 12.5128 = 0.0180 liter = 0.026 gm.
5.467
0.026
Actual amount of O_2 used by flame = 5.441 gm. = (3.807 liters)

$$\text{R. Q.} = \frac{2.521}{3.807} = 0.662$$

First period....0.695
Second period..0.662
Average.....0.677 Theory 0.666; error 1.6 per cent.

Not infrequently a perfectly theoretical result may be obtained in a single period. Often, however, one period shows a slightly high result and the next a correspondingly low result, the mean lying near the theoretical value. This in most cases is due to a rise or fall in temperature of the chamber air, not correctly recorded by the thermometers, caused by a movement of the subject.

Controls with Diabetic Dogs.—Dogs completely under the influence of phlorhizin or deprived of the pancreas have a total incapacity to oxidize glucose. This results in a respiratory quotient which varies but slightly from 0.69. The diabetic dog, therefore, is a suitable subject for controlling the efficiency of respiration apparatus of this type. The following are examples[124] of the quotients which may be expected with dogs which are known, from the relation of glucose to nitrogen in the urine, to be completely diabetic.

Dog VI.	July 9, 1913	R. Q.	11.27–12.27	0.68
			12.27– 1.27	0.68
Dog C.	July 23, 1914	R. Q.	3.42– 4.27	0.69
			4.27– 5.13	0.68
			8.03– 8.49	0.68
Dog E.	Aug. 4, 1914	R. Q.	5.27– 6.27	0.683
			8.27– 9.27	0.685

Animal experiments of this kind furnish a better control of the efficiency of the apparatus for work with infants than does the alcohol flame, for the reason that both the chemical and the physical properties of the air are more nearly like those of an experiment with the child. As a matter of course, the entire air surface is thoroughly sterilized by means of formalehyde, circulated by means of the blower, before the apparatus is used with the infant, and the inner wall of the chamber is scoured or painted, or both.

Oxygen Blank.—This form of control, introduced by Williams,[206] has been useful as a check on the gas analysis. It consists in sealing up the chamber, starting the blower and taking off a sample of air, just as in starting a period for alcohol check, but without a subject or lamp in the chamber. If the air which is thus closed in the circuit is somewhat moist, the water absorbers will remove the water and its place will be taken by oxygen from the cylinder. The same would happen if the temperature were permitted to fall. At the end of an hour another sample of air is taken off for analysis, and after the corrections for temperature and pressure are made, the amount of water lost in the air, as indicated by the residual analyses, should be equal to the amount of oxygen which has been lost from the cylinder. In such a check, the amount of oxygen admitted, say, was 0.346 liter in one hour. The air lost 0.411 liter of water; the carbon dioxide did not change. The temperature had risen 0.2 degrees and the barometer had remained stationary. The temperature change caused an expansion of 0.056 liter in the entire system which would serve to keep out that much oxygen. Hence, (0.346 + 0.056 = 0.402) liter of oxygen, with no temperature change, would have been admitted to replace a (calculated) shrinkage of 0.411 liter.

Registration of Muscular Activity of Infant.—With newborn infants which sleep practically all of the time, the registration of muscular activity is not nearly as important as it is in the case of older infants which normally spend many hours awake and are therefore more likely to move about or cry while in the respiration chamber. For this reason the principal discussion of the methods employed for recording the muscular activity and of the influence of this factor upon metabolism will be taken up in the section devoted to older infants. A few words may be devoted to the subject in this place, however, and a method described which has been found well adapted to the purpose in newborns.

In the experiments which the writer, in conjunction with Dr. H. C. Bailey,[7] conducted upon newborn infants at Bellevue Hospital, it was found that in most instances it was sufficient to have a nurse make frequent observations of the state of quiescence of the infant. This was the more readily accomplished by fastening the bell of a small Bowles stethoscope lightly to the upper front wall of the infant's chest by means of strips of adhesive tape. The rubber tube of the bell passed by an air-tight connection through the walls of the incubator and to this the auriculars of the stethoscope were attached. The connections were made long enough so that the nurse could sit near the machine at a small table, with the auriculars in her ears, and could trace from minute to minute on a ruled chart the exact condition of the child. This method was copied after a similar one used by Schlossmann and Murschauser (p. 634). If the child whimpered or cried suitable notation of the fact was made and the exact time at which this began.

In some instances the child within the respiration chamber was placed upon a pneumatic bed which was made by covering a rectangular box (10 × 22 × 61 cm.), made of galvanized iron, with heavy rubber dam, and cementing it to the rounded edge of the box in such a way as to effect perfectly air-tight closure. Upon the rubber cover a piece of linoleum was fastened with cement. The box thus constructed served as a receiving tambour (Fig. 208). It was connected through the walls of the incubator by means of a wide rubber tubing to a large recording tambour (15 cm. in diameter) placed on top of the incubator and so mounted as to record any vibration of the contained air on a moving drum. In Fig. 208 the entire recording apparatus is shown, removed from the apparatus. A light blanket placed over the strip of linoleum made a very comfortable bed.

Other French Methods.—The other two methods are similar in principle to the respiratory method of Tissot.[193] This consists essentially in having the subject breathe through air-tight nose-pieces or a face mask into a spirometer, and analyzing the air contained in the spirometer at the end of the experimental period. The exact volume of the air being known and the comparison of the inhaled air a simple calculation gives the respiratory exchange of O_2 and CO_2.

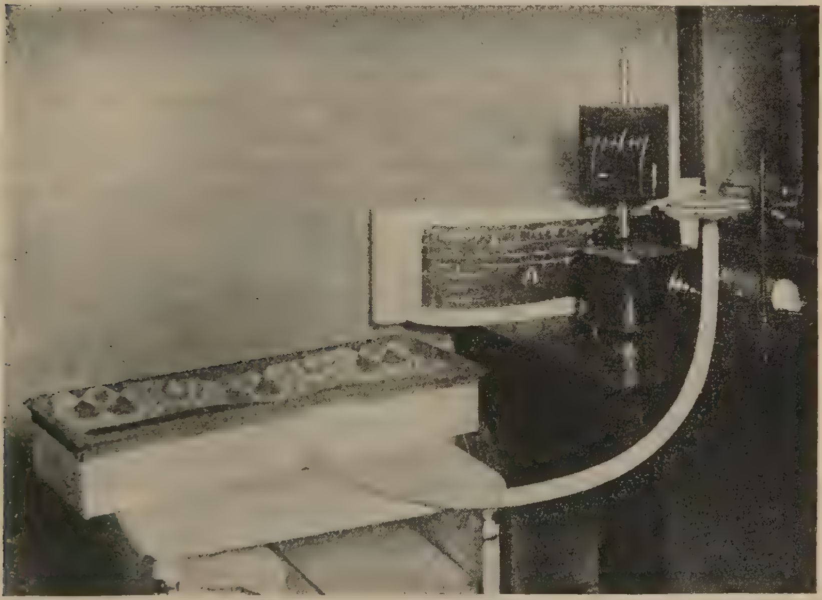


FIG. 208.—Rubber bed used for recording motions of the child, showing the wide tube and large tambour necessary for quick transmission. The character of the tracings obtained is seen in the open book, A. (Amer. Journ. Dis. of Children, Chicago, 1915, IX, Fig. 7, p. 57.)

Hasselbalch[71] in his study of the respiratory exchange of newborn infants already referred to, and Weiss[203] in a similar study which included older infants, analyzed the air coming from or contained in a chamber where the child lay. Since their studies were concerned chiefly with the respiratory quotient, these methods will be described briefly in the next section.

The Respiratory Quotient of the Newborn.—If a sample of pure carbohydrate, *e.g.*, cane sugar, be placed in a bomb and ignited (p. 530, *seq.*), it is possible to learn the amount of combustion by analyzing the gases before and after firing. In the case of pure carbohydrate, it would be found that just as much oxygen by weight has disappeared as is contained in the carbon dioxide produced. Or, since equal volumes of all gases contain the same number of molecules at the same pressure and temperature, it would be found that the CO_2 produced has just replaced the volume of oxygen utilized. This is true because in carbohydrate there is nothing to unite with oxygen except carbon, the hydrogen present being already cared for by the amount of oxygen in the molecule.

The relation of oxygen to carbon dioxide in a combustion of this sort may be called the combustion ratio; and it is evident that if we had a sample of unknown composition, we could learn whether it were a carbohydrate or not by burning it in oxygen and determining the ratio of carbon dioxid produced to oxygen consumed.

The same method may be employed, in fact has been employed, omitting the high pressure of oxygen, in the method of Weiss,[203] to examine the quality of combustion in an infant's body. The child may be sealed up for a time in a closed box containing pure air, or if we like, containing more oxygen than is usually present in the air. With a box containing 60 liters, the child could remain for an hour in this atmosphere without suffering the least harm. If then the air were analyzed at the end of the experiment and its composition compared with that of the air at the beginning, it would be found that the carbon dioxide had replaced the oxygen, or nearly so. If the replacement by volume were exact, *i.e.*, the amount of carbon dioxid added equaling the amount of oxygen withdrawn from the air, it would be a certainty, other factors controlled, that carbohydrate was the material being oxidized in the child's body during the course of the experiment.

In a respiration experiment, this ratio of carbon dioxide produced to oxygen consumed is called the *respiratory quotient.* From it information of crucial importance concerning the metabolism of the infant may be obtained. Interpretation of its value, however, depends upon two primary factors: (1) the technique employed, and (2) the fact that combustion in the animal body is never purely from a single class of substances.

Technique of the Respiratory Quotient.—There are only there possible methods of obtaining the respiratory quotient of the infant. The first method, and perhaps the simplest, is that of Weiss,[203] previously employed by Chauvau and Kaufman, of sealing up the subject in a box and taking a sample of the air for analysis before and after the confinement. Even in so simple a method, however, satisfactory results can only be obtained by careful determination of the water-vapor produced and adequate correction for any changes in pressure and temperature. The chief difficulty falls upon the exact determination of the temperature of the air. Ordinary mercury thermometers have too much lag to record accurately rapid changes of temperature. Hence, if the infant should wake up suddenly and begin to cry after sleeping quietly for a time, the air would be warmed both by the increased respiration and by the extra heat produced by muscular work, and a period terminated at such a moment, or before conditions again become stable, would be a doubtful one from the standpoint of the respiratory quotient.

A second method is that of Hasselbalch.[71] Since it is very difficult to fit a face mask to an infant, Hasselbalch placed the infant in a small cylindrical chamber of 15 liters capacity. Air was admitted at one end and drawn out in a slow stream at the other by means of an ordinary suction pump operated by water pressure. An air-sampling tube filled with mercury was connected with the outlet in such a way as to draw off a continuous sample of the air as it left the chamber, by simply permitting the mercury to flow out in a thin stream. Hasselbalch took the precaution to heat the air to a temperature of approximately 32°C. before admitting it to the chamber, thereby preventing any possible harmful effect of draft. Moreover, the movement of air was at a very gentle rate. With such a method an additional difficulty is introduced, namely, of securing an accurate reading of the volume of air drawn through the apparatus, but this can be accomplished with a carefully calibrated meter, suitable correction being made for the temperature at which the air is measured. The same method is employed for analysis of outgoing and ingoing air.

The third method is that originally introduced by Regnault and Reiset namely, of sealing the subject in a chamber, causing the air to be circulated therefrom into absorbers, which remove the carbon dioxide, and back again to the chamber, the oxygen withdrawn by the subject being replaced from a source of supply outside the chamber. In the apparatus devised by Mareš[111] and employed by Scherer[170] and by Babák[5] in their work upon infants, the oxygen was supplied from a bomb filled under high pressure. In the method of Benedict (p. 560 *seq.*) and in the author's apparatus (p. 563 *seq.*) the carbon dioxide is absorbed by soda lime and the inflow of oxygen from the pressure cylinder is regulated automatically so as to maintain the same tension of atmosphere continuously. The oxygen consumption may be determined by volumetric measurement or by weighing the cylinder at the beginning and end of the period, making suitable correction for changes in temperature and pressure of the atmosphere *and changes in composition of the air itself.* For the highest degree of accuracy the temperature of the air inside the apparatus should be read by means of electrical resistance thermometers of special construction and the air itself should be analyzed at the beginning and subsequently at the end of each period.

Respiratory quotients obtained by any of these methods without careful attention to the technical precautions mentioned are not reliable. Another precaution which is elemental is that no attempt should be made to start an observation period until conditions become stable, whether it be desired to record the respiratory quotient of quiet sleep or that of severe crying. The reason for this is that in severe crying there is for a time an exaggerated elimination of carbon dioxide, just as there is with an adult when respiring for the first time through a face mask; while in a period of quiet sleep immediately following severe crying, just as after severe muscular work in man, there is for a time a period when less CO_2 is being eliminated than is being produced. The previous depletion of the tissues of their normal content of CO_2 is being restored. In the first set of conditions, the start of a fit of crying, the respiratory quotient would be too high, and in the second set of conditions, the first spell of quiet following, the quotient would be too low.

Other possibilities closely related to the conditions just named, which must be borne in mind if a correct interpretation of the R. Q. is to be made, are the following. If the child should be partially asphyxiated, as every child is at the moment of birth, the first respirations ensuing thereafter will be scarcely normal. There is an excess of CO_2 in the circulating blood, consequently there may be for a time an excess of CO_2 in the expired air. There may be also a deficit of oxygen in the newly-established circulation and consequently the amount absorbed may be more than necessary to support combustion. How long these conditions may persist is not at all known (p. 579).

Again, if oxygen is being used in the body for any purpose whatsoever, other than that of combustion, be it synthesis in growth of oxygen-rich substances (*e.g.*, phosphates from organic phosphorous), or for the formation of glucose from protein (still more if it is ever formed from fat), the respiratory quotient will tell the story if adequately, *but only if adequately*, controlled.

Once more, abnormally, as we know well from the study of adult metabolism, there may be formation of sugar from proteins (diabetes) and there may be acidosis from incomplete combustion (in a variety of conditions). Under either of these circumstances oxygen-rich substances are being made out of oxygen-poor substances and oxygen taken in by the lungs is not returned as carbon-dioxide, but may be excreted in such combinations through other channels. The effect would be to produce a respiratory quotient lower than normal. A high quotient, conversely, would be produced if under any circumstances, normal or abnormal, an oxygen-poor substance was made out of an oxygen-rich substance, so that some oxygen taken into the body as food were available for combustion. The most familiar condition of this sort is the formation of fat from carbohydrates. High quotients have been demonstrated in fattening geese, in fattening hogs, and in dogs stuffed with more carbohydrate than they could oxidize at the time.

Respiratory Quotients of Different Food Stuffs.—These relations will be more intelligible when the actual chemical reactions involved are studied quantitatively. We start again with the simplest condition, that of the combustion of carbohydrates. Glucose, the normal sugar of the blood, is oxidized thus:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$$

The relation of CO_2 by volume to the O_2 is $\frac{6CO_2}{6O_2} = 1.0$ or, the relation by weight of the O_2 in CO_2 to O_2 absorbed is $\frac{6O_2}{6O_2} = 1.0$. The respiratory quotient is unity. When a simple fat like palmatine, $C_3H_5(C_{16}H_{31}O_2)_3$ is burned, conditions are as follows: The fat may be written thus: $C_{51}H_{98}O_6$ and its combustion would proceed according to the following equation:

$$C_{51}H_{98}O_6 + 72.5O_2 = 51CO_2 + 49H_2O$$

The relation of CO_2 by volume to the O_2 is $\frac{51}{73.5} = 0.703$, which is the respiratory quotient. With a simpler fat such as the butyrate: $C_3H_5(C_4H_7O_2)_3$, the relationship would be quite different, owing to the relatively larger quantity of O_2 already present in the molecule. Thus:

$$C_{15}H_{26}O_2 + 18.5O_2 = 15CO_2 + 13H_2O$$

The respiratory quotient would be $\frac{15}{18.5} = 0.81$. Food fats are for the most part composed of the glycerides of palmitic, stearic, and oleic acids, an average composition on the percentage basis being 76.5 per cent. C; 11.9 per cent. H; and 11.6 per cent. O One hundred grams of such a fat would require 288.6 gm. O_2 in addition to that already present in the molecule for complete conversion to CO_2 and H_2O. There would be produced 280.5 gm. CO_2. The relationship of $\frac{CO_2}{O_2}$ is $\frac{280.5}{288.6}$ and this divided by $\frac{44}{33}$, the molecular weights, or multiplied by $8/11$, would give the respiratory quotient, 0.706. A slightly simpler calculation, as noted above, is to determine the weight of O_2 necessary to form CO_2 (in this case 204.0 gm.) and divide this directly by the weight of total O_2 required; thus: $\frac{204.0}{288.6} = 0.706$

The respiratory quotient of all food fats is in the neighborhood of 0.71. The same is true also of body fat. Hence, whether pure body fat or pure food fat were being burned, the R.Q. would be approximately 0.71. As a matter of fact, this quotient is probably never actually produced under normal conditions; for there is always some protein being destroyed, and, since under the conditions of high fat combustion, whether from starvation or excessive fat ingestion this small amount of protein is readily oxidized, there is a mixed quotient contributed in small part by the oxidation of protein and in large part by the oxidation of fat. On the assumption that the protein quotum of energy production is 15 per cent. and the other 85 per cent.

is from fat, Magnus-Levy[110] estimates that the actual respiratory quotient should be 0.722, while if the remaining 85 per cent. is produced from carbohydrate, the quotient should be 0.971.

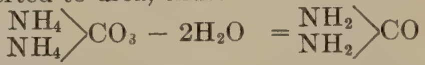
The respiratory quotient of proteins will, of course, depend upon the exact formula employed; but since all proteins are made up of amino acids, the exact relationship can best be appreciated by starting with a single amino acid. If alanin is given to an animal, it will be oxidized after deamination, as follows:

$$CH_3 \cdot CH \cdot NH_2 \cdot COOH + H\ OH = CH_3 \cdot CH \cdot OH \cdot CO\ OH + NH_3$$
$$CH_3 \cdot CH \cdot OH \cdot COOH + 3O_2 = 3CO_2 + 3H_2O.$$

The respiratory quotient of this reaction would be 1.0 since the volume of O_2 is just equal to the volume of CO_2 produced. But the NH_3 is not yet disposed of. It cannot remain in the body as NH_3 and it can not be eliminated as a gas, for the lungs are not permeable to NH_3 even if it could be carried in the blood as a gas. Actually, the NH_3 will unite with the CO_2 to form ammonium carbonate, thus:

$$2NH_3 + CO_2 + H_2O = (NH_4)_2CO_3$$

Later, this is converted to urea, thus:



$$\begin{matrix} NH_4 \\ NH_4 \end{matrix} \rangle CO_3 - 2H_2O = \begin{matrix} NH_2 \\ NH_2 \end{matrix} \rangle CO$$

The net result would be that for each two molecules of alanin, yielding two molecules of NH_3, one molecule of CO_2 would fail to appear in the expired air, but would be eliminated as urea or water. Hence, for six molecules of O_2 absorbed, only five would come back as CO_2 and the true R. Q. of alanin would be five-sixths = 0.833. If all proteins were made up of amino acids as simple as this, the R. Q. for their combustion would be as easily computed. The respiratory quotient of glycocoll would be 0.75; that of leucin would be 0.73. But that of lysin containing two NH_2 groups and requiring, therefore, one molecule of CO_2 for elimination of the N as urea for each single molecule of the substance, would be only 0.71. The more diamino-acids contained in a protein, therefore, and the more leucin, the lower would be the respiratory quotient. With gelatin, which contains a high percentage of glycocoll, one might expect a somewhat higher quotient than with casein which contains no glycocoll and a much larger amount of leucin. Taking an example of a highly synthetized protein such as l-leucyl-triglycyl-l-leucyl-triglycyl-l-leucyl-octoglycyl-glycin,[1] which was put together by E. Fischer and whose exact chemical structure is therefore known, we find that 45 molecules of O_2 would be necessary to produce complete combustion; that nine molecules of CO_2 would be needed to remove the NH_3 in the form of $(NH_4)_2CO_3$; and that when this ammonium carbonate breaks down by dehydration to form urea, none of the carbon would return to the respiration and none of the oxygen would be available for combustion. The R. Q. therefore would be 0.866.

Taking the elementary analysis of protein of the human body and adopting the percentages used by Magnus Levy,[110] we get the following composition after making allowances for the elements which would appear in the urine and the feces: C, 38.6 per cent.; H, 4.24 per cent.; O,9.24 per cent. For the combustion of 100 gm. of such protein 127.6 gm. O_2 in addition to that already present in the molecule would be needed and 141.5 gm. CO_2 would be formed. Taking the ratio of the oxygen in CO_2 (102.9 gm.) to the total oxygen required, the quotient is 0.807, or by the longer calculation $\frac{141.5 \text{ gm. } CO_2}{127.6 \text{ gm. } CO_2} \times \frac{8}{11} =$ 0.807. The respiratory quotient of a complete protein such as is ordinarily used in rebuilding the human tissues, but which, because it is not needed for this purpose is oxidized as completely as it is possible to oxidize protein in the body, is thus approximately the same as that for alanin. We may think of this amino acid as representing the type of fuel available when protein is burned.

TABLE 7

R. Q.	Carbohydrate, per cent.	Fat, per cent.
0.707	0.0	100.0
0.71	1.4	98.6
0.72	4.8	95.2
0.73	8.2	91.8
0.74	11.6	88.4
0.75	15.0	85.0
0.76	18.4	81.6
0.77	21.8	78.2
0.78	25.2	74.8
0.79	28.6	71.4
0.80	32.0	68.0
0.81	35.4	64.6
0.82	38.8	61.2
0.83	42.2	57.8
0.84	45.6	54.4
0.85	49.0	51.0
0.86	52.4	47.6
0.87	55.8	44.2
0.88	59.2	40.8
0.89	62.6	37.4
0.90	66.0	34.0
0.91	69.4	30.6
0.92	72.8	27.2
0.93	76.2	23.8
0.94	79.6	20.4
0.95	83.0	17.0
0.96	86.4	13.6
0.97	89.8	10.2
0.98	93.2	6.8
0.99	96.6	3.4
1.00	100.00	0.0

The Non-protein Respiratory Quotient.—In the exact computation of the heat production, as we shall see beyond, it is customary, following the method introduced by Zuntz and Schumburg,[209] to compute the amount of oxygen of the respiration which is employed in the oxidation of the protein metabolized (as judged by the excretion of nitrogen in the urine) and to subtract this from the total oxygen intake. It is thus possible to arrive at what is called the non-protein respiratory quotient, upon the level of which depends the heat value of the oxygen which has been absorbed. Table 7 on p. 577 gives the proportion of carbohydrate and fat necessary to produce each non-protein respiratory quotient, expressed in two figures, from 0.70 to 1.00. The heat value of the oxygen varies from 4.686 Calories per liter with the respiratory quotient at 0.70 to 5.047 Calories per liter when the quotient is 1.00 (p. 587).

Points of Practical Interest in the Respiratory Quotient of the Newborn.—In the observations of Mensi,[116] Scherer, and Babák, the respiratory quotient of the newborn child was found to be extremely low, so much so that it was inferred that oxygen must be utilized in the infant's body for some other purpose than that of combustion. More recent observations have discredited this interpretation, for it has been rendered very probable that the technique of the early observers was

TABLE 8.—RESPIRATORY QUOTIENTS OF INFANTS IMMEDIATELY AFTER BIRTH (HASSELBALCH)

Experiment number	Sex	Body-weight, grams	Height, centimeters	Age, hour minute	Remarks on food and muscular repose	CO_2 elimination per kg. per hour at 0°C. and 760 millimeters	R. Q.
9	F.	3750	51	0:45	No food; quiet throughout; slept latter half of experiment.	333 c.c.	0.970
3	M.	3100	51	1:30	No food; bath; crying and kicking 1 minute; otherwise contented; sucking or half asleep.	481	0.868
8	F.	3950	54	1:30	No food; quiet, now and then sucking; otherwise without movements throughout experiment. No crying.	270	0.862
12	F.	4000	54	1:30	No food; rather restless; hungry; now and then crying.	399	0.794
2	F.	3650	51	2:00	No food; during most of experiment quiet and contented; now and then sleeping; cried about one-half minute fat and strong.	422	1.012
7	M.	3200	50	2:00	No food; rather quiet; now and then kicking and trembling as if cold; no crying.	457	0.909

seriously at fault. Hasselbalch points out that Scherer's oxygen must have contained a much larger percentage of nitrogen than he assumed, from an old analysis,to be present; also that there was an admitted error of 6 per cent. on the carbon dioxide.

Hasselbalch himself obtained quotients which were much higher. Since his technique (which was described on page 573) seems to have been carefully controlled, it is probable that his results are much more reliable. In fact, Hasselbalch lays stress on the fact that the R. Q. of the newborn infant before it begins to take food is often much higher than that of an adult in a similar state of inanition, and he thinks it is fair to infer that in such cases, which in his tables include both the well-nourished infants born at term, and infants prematurely born, there is a plentiful amount of glycogen available at birth and it is the requisition upon this reserve carbohydrate which produces the high quotients. Since Hasselbalch's work was published only in Danish and is not yet as well-known as it should be, several of his tables are here reproduced.

Hasselbalch infers much from the single experiment of Bohr on the pregnant guinea pig (quoted at page 555) showing that the respiratory quotient of the embryo is 1.0. It is quite possible, as the writer has elsewhere[122] indicated, that this is true, but the single experiment of Bohr can hardly be accepted as proving the case beyond a doubt. Recent analyses[118] of the blood of the mother and of the umbilical vein taken simultaneously at parturition show clearly that other materials than glucose can pass the placenta very readily, and while one may be prepared to believe that the main reliance of the embryo for energy is the most diffusible of the foodstuffs, it must not be inferred that no other substance is available for combustion in the fetus. Were carbohydrate the only fuel available during antenatal life, it might be argued that the enzymes are not yet ready for liberation of energy from fat, (which certainly is present) even if a large store of glycogen could not be demonstrated; and we might expect to find the quotients rather higher immediately after birth than a little later. Hasselbalch himself admits that the facts are not quite so easily explained. Referring to Table 8, it is seen that the highest quotients do not always come at the earliest hour. When the same subject was used in two successive experiments, however, (Table 9) this was found to be true.

So convinced was Hasselbalch that the quotient was higher the better the state of nutrition of the newborn that he thought he could tell when the quotient was lower than 0.9 by signs of hunger in the infant.

The occurrence of high quotients within the first seven or eight hours after birth was observed independently also by Bailey and Murlin.[7] They drew attention to the particular interest which the quotient at this time presents, as indicating the kind of material available for combustion as the child breaks connection with the maternal circulation. They were on their guard, however, against inferring, without further information regarding the absorption of oxygen at this age, (p. 574), that the high quotient necessarily proves a predominantly carbohydrate combustion. "Assuming that oxygen absorption is normal at this early age," they say, "the quotients obtained would indicate the combustion of a considerable amount of carbohydrate (glycogen)." Since Morris[117] has published his sugar analyses in maternal and umbilical bloods and has shown that the level of the blood sugar is raised in both by a severe labor or by the use of an anaesthetic, another explanation of the high quotients which are met with in the early hours of post-natal life has been presented.[128] Henceforth it will be necessary to know something of the severity of labor and whether the mother was given an anesthetic, before a plentiful supply of glycogen in the liver of the newborn all ready for com-

TABLE 9.—FALL IN RESPIRATORY QUOTIENT OF THE NEWBORN (HASSELBALCH)

Experiment number	Sex	Body-weight, grams	Height, centimeters	Age, hour minutes	Remarks on food and muscular repose	CO_2 elimination per kg. per hour at 0°C. and 760 millimeters	R. Q.
17	M.	3400	52	0:30	No food; no bath; wide awake; quite contented; no crying.	344	0.933
18	M.	3400	52	1:45	Hungry and sleepy in last two-thirds of experiment. Sleeping and waking; no crying.	275	0.854
13	M.	4500	53	0:45	No food; no bath; awake and contented.	488	0.921
14	M.	4500	53	1:45	Sleeping quietly during nearly the whole experiment.	300	0.808
19	M.	3600	54	1:30	No food; bath; good condition; considerable birth swelling; lively and contented; later hungry and somewhat sleepy.	400	0.921
20	M.	3600	54	2:30	Stupid; fell asleep now and then; but awake most of time; cried one minute. At last lively.	306	0.849
10	M.	2750	47	0:15	No food; no bath; born three weeks before time; crying about one-third of time.	462	0.912
11	M.	2750	47	1:00	Quieter; crying about one-fourth of time.	420	0.897
15	F.	1900	..	5 days	Incubator infant; weight at birth 1950 gm. takes to breast poorly; put to breast every two hours last time just before experiment fast asleep.	205	0.770
16	F.	1900	..	5 days	Incubator infant; weight at birth 1950 gm. takes to breast poorly; put to breast every two hours last time just before experiment fast asleep.	235	0.806

bustion the moment the cord is tied, can be inferred. However, it is possible that the severe labor would mobilize glycogen from the maternal tissues and that ether administered would mobilize it from both the maternal and fetal tissues, so that the umbilical vein would get a contribution from both directions. Hasselbalch's insistence upon a relationship to general nutritive condition is not necessarily discredited, for it is well-known that in the majority of instances a large, well-formed infant produces a more difficult labor which itself, without the assistance of an anaesthetic, would in all probaility call out enough carbohydrates into the circulation to raise the quotient several points. Premature infants also produce early labor, and this fact with absence of a hyperglycemia may explain the impression of Hasselbalch that in the prematurely born infant "the store of carbohydrate is very quickly spent."

Benedict and Talbot[23] did not observe expecially high quotients immediately after birth; for the technique of their experiments was not calculated to separate the respiratory quotients into individual periods. The authors state, however, that when the quotients above and below 0.80 are compared, it is found "that up to the eighth hour the greater number lie above 0.80, while subsequent to the tenth hour the larger proportion lie below this value." Notwithstanding Hasselbalch's statements that his infants which showed high quotients were quiet, Benedict and Talbot are of the opinion that his high quotients are due "not to the larger proportion of glycogen taking part in the combustion, but to an increase in the carbon dioxide excretion owing to a disturbance in the mechanics of respiration." This explanation, however, is rendered improbable by the considerations regarding blood sugar just recited.

All the modern observations agree in showing a rapid fall in the respiratory quotient toward the end of the first day. Hasselbalch did not repeat his observations on the same infant except in immediately succeeding periods. But even these second periods show in four out of five cases, (Table 9) a noticable fall. Bailey and Murlin made observations on two infants born three hours apart on the same day and placed in the respiration incubator at six hours of age. The observations were repeated on the second, fourth, fifth, and sixth, days with one child, and on the second, fourth, fifth, and eighth, with the other. The quotients fell to 0.67 in both cases on the second day. While distrusting the exact figures obtained, the authors point out the extreme significance of the indication, confirmed on a third newborn at the twenty-fourth hour, that all available carbohydrate has been utilized by this time, and the importance of supplying artificially, if need be, some materials to protect the body substance. Mother's milk was available in small amount for both infants on the third day, but the quotients did not reach the level usually obtained after breast feeding of older babies until the sixth day in one instance and the eighth in the other. These observations were confirmed by Benedict and Talbot[23] in their long series, the following values having been obtained as averages of several short periods for each infant.

Day—	1	2	3	4	5	6	7	8
Respiratory quotient	0.80	0.74	0.73	0.75	0.79	0.82	0.81	0.80
Number of cases	74	64	62	51	41	22	15	9

The Influence of Food.—Milk appears in the mother's breast usually by the fourth day, and by the fifth day the infant receives enough to prevent further loss in weight (pp. 612, 613). The course of the average respiratory quotient from the first to the eighth days reflects the adequacy of the food intake. Unless artificial feeding is resorted to, the modern infant is doomed to almost complete starvation for the first three days, although it is clear that glycogen is present in sufficient quantity to prevent starvation acidosis the first day. When milk comes in sufficient quantity on the fourth day, the average respiratory quotient responds noticeably and on the fifth and sixth days amounts to a level which indicates a satisfactory state of nutrition.

The question has often arisen whether the newborn infant is capable at once of digesting and metabolizing a sufficient quantity of breast milk even if it were present, to prevent loss of weight. The answer to this question must be sought by means of the respiration apparatus. The matter will be discussed in its quantitative aspects at greater length beyond. Meantime, it may be noted that Hasselbalch has tested the capacity of the newborn to absorb and metabolize grape and milk sugar and that perfectly satisfactory evidence was obtained from the respiratory quotient that this capacity is developed by the end of the second day. The table which follows is compiled and slightly modified from Tables 4 and 5 of Hasselbalch's[71] paper as translated by Miss Johnson.

TABLE 10.—EFFECT OF SUGAR ON THE R. Q. OF NEWBORN INFANTS (HASSELBALCH)

Number	Sex	Weight, grams	Age, hours	How fed	Last food and when	CO_2 eliminated per kg. and hour, cubic centimeters	R. Q.
23	F.	2550	15	Breast	Immediately before experiment.	283	0.69
26	F.	2450	48	Breast	Grape sugar one-half hour before experiment.	370	0.87
28	M.	3000	15	Breast and bottle	Immediately before experiment.	482	0.85
29	M.	2950	48	Breast	Milk sugar one and one-quarter hours before experiment.	617	1.03
1	F.	3700	3		Sugar water at birth, three hours before.	500	0.90

The results in experiments 23 and 26 are the more noteworthy because of the fact that the infant was born two to three weeks prematurely. Infants born prematurely may have a high R. Q. within the first few hours after birth (Table 8); but by the fifteenth hour the supply of glycogen, or the hyperglycæmia due to labor and anesthesia or both, have been considerably reduced and, as noted here, the child may be already on a nearly pure fat metabolism. Several feedings of grape sugar intervened, one of which immediately preceded the second experiment. The level of the quotient shows that this material was burning. With the adult subject an identical result could be obtained with a sufficient quantity of sugar following a period of fasting. When an adult mammal already well nourished is given even a small quantity of easily absorbed sugar, the effect upon the R. Q. may be seen within the first half hour. When, on the other hand, fat is given in large amount, the effect upon the quotient may not be seen until the third to sixth hour.[127] We may expect then that in feeding an infant with milk, whether mother's or cow's milk, it is the sugar of milk which is burned first and the fat will only be absorbed in sufficient quantity to affect the R. Q. after several hours.

The work of Hasselbalch demonstrates these points also very clearly. After feeding infants two and five days of age with breast milk, he found the highest quotient (0.92 and 0.93) one and one half hours after the meal. In one case he was able to show that an experiment begun two hours after a feeding gave a quotient four points lower than an immediately succeeding period begun only one hour after a similar feeding. Apparently in Hasselbalch's experiments, as in those of Bailey and Murlin, it is much easier to secure this rise of quotient with infants five days or more of age than it is with those of two days or less. The explanation clearly is that unless artificial nourishment has been resorted to, the infant's tissues are depleted of glycogen at two days just as are those of an adult after several days of fasting[91] and anything less than a large feeding af carbohydrate is held up by the tissues to satisfy their craving for storage glycogen.

Practical Considerations.—The practical points brought out by this discussion of the respiratory quotient may be summarized as follows:

1. The respiratory quotient immediately after birth instead of indicating, as formerly taught, that oxygen is used for some other purpose than combustion, in the majority of instances indicates rather that there is an abundance of carbohydrate availale for combustion at once.

2. This carbohydrate may be present in the form of glycogen stored in the infant's tissues or as extra sugar in the circulation, a hyperglycaemia having been demonstrated by Morris as the result either of a severe labor or of anaesthesia. Studies in respiratory metabolism of newborn infants have not as yet taken account of this hyperglycaemia.

3. The respiratory quotient falls rapidly from birth until at the end of the first 24 hours or even earlier it indicates that very little glycogen remains and that any hyperglycaemia has passed away.

4. Premature infants likewise show high respiratory quotients imme-

diately after birth, but probably because of a greater demand for growth as indicated by the observations of Rubner and Langstein,[165] they lose any extra carbohydrate more quickly than do infants born at term.

5. The respiratory quotient is a sure index of the adequacy of nourishment obtained the first week of life. Unless artificial nourishment is resorted to, the respiratory quotient shows that the infant is on a starvation basis the second, third, and often the fourth days.

6. Studies by Hasselbalch indicate clearly that the infant at term, or even if born prematurely, is able at once to burn either grape sugar, milk sugar, or cane sugar.

7. When milk is once fully established in the breast and the infant receives a liberal feeding, the respiratory quotient is highest about one and one-half hours after the feeding, indicating that at this time the milk sugar is being absorbed most rapidly. Studies of the respiratory quotient should be used to determine the optimum frequency feeding.

Basal Metabolism in the Newborn.—It is an observation at least as old as the science of nutrition that the young of all mammalian species consume an amount of food out of all proportion to their weight as compared with adults. Carl Voit was one of the first to appreciate the importance of this fact and to be interested in its explanation. He set one of his pupils, Forster, to study the respiratory metabolism of infants and young children by means of the apparatus designed by Pettenkofer and himself. The result was the first generalization concerning the energy metabolism of infants, and one that may used to introduce the subject for the newborn.

In the brief account of his experiments published in the proceedings of a local society, Forster[55] refers to measurements of food intake upon artificially and breast-fed infants, as well as to estimations upon older children made by Professor Voit. The question he sets himself is whether the observed high consumption is a dispensable luxus or a necessity, and he notes that it can only be answered by determination of the fat (that is, non-nitrogenous) metabolism; for with protein as had been shown by Voit, the amount destroyed is determined by the intake. Forster made fourteen experiments on children from two weeks to nine years of age while they were resting and approximately fasting and found they agreed in showing that for each 10 kg. of body-weight the carbon dioxide output was 10 to 12 gm. per hour, while for the adult under the same conditions, as had already been shown in the same laboratory, the output is only 4 to 5 gm.; with moderate amount of food 5 to 6 gm.; and only 7 gm. when, in addition, a moderate amount of work is done. It is therefore certain, says Forster, that the youthful organism in the fasting and resting condition (basal metabolism) produces at least twice as much carbon dioxide "or destroys at least twice as much fat" as the adult. Forster concludes by noting that when the greater bodily activity of the child is taken into account, it is evident that the greater consumption of food is a matter of necessity.

The discovery that this level of metabolism is true also of the newborn child was made by Scherer[170] but was scarcely recognized by him because his attention was centered on another matter. Scherer was the first to make an extended series of observations on the newborn. With an apparatus very much like the original Regnault and Reiset apparatus, constructed in the physiological laboratory at Prague by Professor Mareš, he made altogether 85 experiments, some 30 of which were upon infants less than 24 hours of age. Scherer found as a mean of all his observations on infants up to nine hours of age at summer temperature (16 to 27°C.) a carbon dioxide elimination of 320 c.c. per kg. and hour compared with 216 c.c. observed by Laves[96] on a man 30 years of age. The oxygen absorption was 470 c.c. per kg. and hour compared with 243 c.c. for the adult man. The respiratory quotient obtained by these figures on the infant is exceedingly low (0.67 av.) and it is highly probably that there was an error upon the determination of the carbon dioxide as well as of oxygen. The results are given here, however, by way of general corroboration of the results published by Forster, which likewise could not have satisfied present day requirements for accuracy. Both series served to draw attention sharply to the very great discrepancy between the metabolism of infant and adult on the basis of weight. This has been abundantly confirmed since. It was many years after this that Rubner[161] calculated the metabolism of a newborn mammal to be approximately twice that of the mother on the basis of weight.

Forster's estimate of the metabolism of young children, as a matter of fact, included one determination[57] only upon a newborn infant, and this one was 14 days old. It shows the metabolism somewhat less than the average of the entire 14 observations on children up to nine years of age. Scherer also noted a very considerable difference between infants up to four days and those between this age and four weeks of age. Later observations have confirmed these generalizations as well, and we may state at once that the metabolism per unit of weight of infants and young children varies with age.

Carpenter and Murlin[38] found the metabolism of the newborn (up to two weeks of age) to be two and a half times that of the mother lying in bed beside the child. Later observations by Benedict and Talbot[23] and by Bailey and Murlin[7] make the figure for newborns less than a week old 1.75 and 1.87 calories respectively per kilogram and hour as against 1.0 calorie per kilogram and hour for the normal adult. The figure given by Benedict and Talbot is the average for observations on nearly one hundred subjects which ranged from two and a half hours to seven days in age, and had an average age of two days. That given by Bailey and Murlin is the average of 12 hourly periods on four infants less than one week of age, during which the infant slept all or substantially all of the time. On the basis of 24 hours at the same rate, the metabolism would be 42 calories per kilogram according to Benedict and Talbot or 45 calories per kilogram and 24 hours according to Bailey and Murlin. It should be noted however that the periods selected for this average represented the periods of unusual muscular repose, and that no infant would ever actually maintain a metabolism so low for an entire 24-hour period. It avoids confusion, therefore, to report all results of metabolism experiments done in short periods on the hourly basis; for it is obvious that when a child sleeps quietly for the entire period, as it did in most instances in the two series of experiments referred to, the metabolism obtained does not represent an average condition for the entire 24 hours. In fact it would be next to impossible to find a short period or to arrange conditions for one which could be said to represent average conditions for 24 hours. Moreover a child does not metabolize materials in periods of 24 hours as an adult may be said to do. If there is any cycle of metabolism in the newborn, it corresponds to the feeding period. With this explanation the chart above taken from Benedict and Talbot[23] may be presented. The heavy diagonal line represents the average of all their observations, *i.e.*, 42 calories per kilogram and 24 hours. The lighter lines represent plus and minus 10 per cent. from this average. The great majority of the cases fall within these limits which represent the usual degree of variability in metabolism.

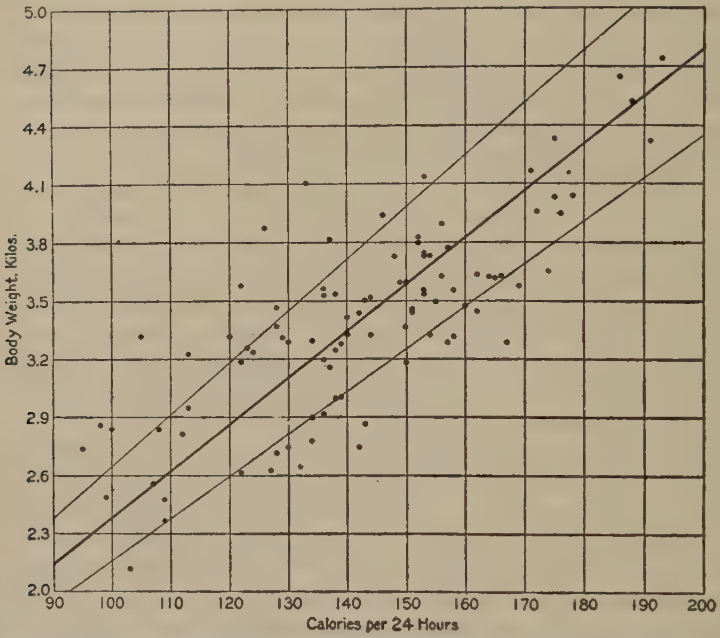


FIG. 209.—Basal metabolism of newborn infants on basis of 24 hours referred to body weight. ——— mean; (———, ten per cent. above and below the mean). (Benedict and Talbot, Carn. Inst. Publ. #233, Wash., D. C., 1915, Fig. 4, p. 97.)

Computation of Basal Metabolism.—Attention should be directed at this point to a difference in the accuracy of the computation of the metabolism upon the carbon dioxide elimination as compared with the oxygen absorption as a basis. The table below shows the heat value for a liter of each gas, as reckoned by Zuntz and Schumburg,[209] for each respiratory quotient expressed in two figures, when the protein combustion has been eliminated. It will be noted that there is a variation of 25 per cent. in the heat value of a liter of CO_2 from the lowest to the highest quotient, but a variation of only 6 per cent. for a liter of oxygen over the same range. The computation based upon oxygen, if there should be any error on the respiratory quotient, is therefore more accurate.

TABLE 11.—HEAT VALUE OF OXYGEN AND CARBON DIOXIDE FOR DIFFERENT NON PROTEIN RESPIRATORY QUOTIENTS

Calorie value of one liter of

R. Q.	CO_2	O_2	R. Q.	CO_2	O_2
0.70	6.694	4.866	0.86	5.669	4.875
0.71	6.606	4.690	0.87	5.617	4.887
0.72	6.531	4.702	0.88	5.568	4.900
0.73	6.458	4.714	0.89	5.519	4.912
0.74	6.388	4.727	0.90	5.471	4.924
0.75	6.319	4.739	0.91	5.424	4.936
0.76	6.253	4.752	0.92	5.387	4.948
0.77	6.187	4.764	0.93	5.333	4.960
0.78	6.123	4.776	0.94	5.290	4.973
0.79	6.062	4.789	0.95	5.247	4.985
0.80	6.001	4.801	0.96	5.205	4.997
0.81	5.942	4.813	0.97	5.165	5.010
0.82	5.884	4.825	0.98	5.124	5.022
0.83	5.829	4.838	0.99	5.085	5.034
0.84	5.774	4.850	1.00	5.047	5.047
0.85	5.721	4.863			

Influence of Birth-weight on Metabolism.—The influence of weight on the metabolism per unit of weight is well illustrated by the following table from Bailey and Murlin. The metabolism is noticeably higher for a light-weight baby (W, birth-weight 6 pounds) than for a heavy baby (B, birth-weight 10 pounds, 3 ounces). From considerations which will be presented in discussion of metabolism of older infants, it is practically certain that the principal factor responsible for such a difference is the insulating effect of subcutaneous fat or of the effect of fat to reduce the effective radiating surface.

The average heat production of all of the infants over 4.00 kg. body-weight and over one day of age in Benedict and Talbot's[23] Table 12 is 1.75 calories per kilogram and hour, while the average of all those between 2.70 and 3.00 kg. in weight and within the same range of ages is 2.00 calories per kilogram and hour. The observations of Benedict and Talbot are thus in substantial agreement with those of Bailey and Murlin. One cannot say, however, that all individual cases in these groups between the extreme limits show a metabolism which is inversely proportional to weight. The influence of body-weight (fat) can be shown best by contrasting the extremes.

TABLE 12.—INFLUENCE OF WEIGHT ON METABOLISM OF THE NEWBORN (BAILEY AND MURLIN)

Weight, kilograms	Age, hours	Calories per hour	Calories per kilogram and hour	Calories per square meter and hour (Meeh)
W. 2.9	6	5.649	1.94	23.67
B. 4.6	6	6.724	1.46	20.43
W. 2.82	31	6.255	2.22	26.54
B. 4.49	31	8.704	1.94	26.87
W. 2.75	80	5.972	2.18	25.57
B. 4.27	80	7.101	1.66	22.67
W. 2.75	104	5.252	1.83	21.85
B. 4.27	104	7.500	1.77	23.47
W. Average	...	5.782	2.04	24.43
B. Average	...	7.514	1.70	23.36

Within the age of one week the metabolism is by no means constant. The average for 31 cases less than 12 hours of age is, according to the results of Benedict and Talbot, 1.59 calories per kilogram and hour, while for their 10 infants from 12 to 22 hours of age it is 1.87 calories. Beyond the first day there is but little fluctuation in the average. Thus for 14 infants two days old the average is 1.86 calories per kilogram and hour and for 13 infants, four, four and a half, and five days of age, the average is 1.85 calories. It is evident from these calculations that the lower value noted above for Benedict and Talbot's longer series is due to the large number of infants less than 12 hours of age included in their observations. Summing up all the modern results, it may be stated categorically that the metabolism per unit of weight for the first 12 hours is approximately 15 per cent. lower than it is the rest of the first week. As will appear more clearly beyond, another factor in this may be the imperfect regulation of heat production in response to heat loss which was found by Babák[5] to be characteristic of the early days of post-natal life.

Metabolism per Unit of Body Surface.—When the metabolism per unit of surface area of the newborn is compared with that of the adult, account must once more be taken of the actual age. The average for the first two weeks may be illustrated by the following table from Carpenter and Murlin slightly modified by Lusk.[105] Here it is seen that the metabolism of the pregnant mother with an average weight for the three subjects of 63 kg. was 33.4 calories per square meter of body surface (Meeh's formula). After parturition the average weight was 53 kg. and the heat production 33.2 calories per square meter. The average heat production for women between 20 and 50 years, according to Benedict and Emmes,[18] is 32.3 calories per square meter. Now the still more remarkable fact is that the metabolism of the child (determined by difference between the metabolism of mother and child taken together and mother alone) with an average body-weight of 3.10 kg. is 33.4 calories per square meter of body surface—exactly the same as that of the mother whether before or after parturition. A more striking agreement in accordance with the law of surface area would indeed be difficult to find. A woman heavy with child, the same woman immediately after delivery, the child itself, and normal non-pregnant women, differing enormously in weight and showing a metabolism per unit of weight differing two and a half times, have the same metabolism when this is reckoned on the basis of surface. The agreement, in fact, is too close to represent the exact truth, except for the circumstances presented by chance in these particular experiments. We now know from the further work of Murlin and Hoobler,[126] as well as that of Benedict and Talbot,[22] that the exact

TABLE 13.—METABOLISM BEFORE AND AFTER PARTURITION. THE METABOLISM OF THE CHILD WAS DETERMINED BY DIFFERENCE

	Weight in kilograms	Calories per hour	Calories per square meter (Meeh)	Calories per kilogram per hour
Case I:				
Before parturition	63.0	60.7	31.4	0.96
After parturition	51.4	53.9	31.7	1.05
Difference	11.6	6.8		
Child	2.7	7.3	30.5	2.70
Case II:				
Before parturition	58.0	64.7	35.1	1.11
After parturition	48.5	59.0	36.2	1.21
Difference	9.5	5.7		
Child	3.4	9.8*	34.9	2.88
Case III:				
Before parturition	69.1	70.6	34.0	1.02
After parturition	60.1	60.4	31.9	1.00
Difference	9.0	10.2		
Child	3.2	9.3	34.8	2.90
Average:				
Before parturition	63.4	65.3	33.4	1.03
Child	53.3	57.8	33.2	1.09
After parturition	3.1	8.8	33.4	2.82

*Child cried during the experiments.

TABLE 14.—HEAT PRODUCTION OF NEW-BORN INFANTS (BAILEY AND MURLIN)

Number	Name	Age at beginning of observation	Average pulse rate	Condition	Calories per hour	Calories per kilogram per hour	Calories per square meter per hour		
							$11.9\sqrt[3]{(W)^2}$ (Meeh	$10.3\sqrt[3]{(W)^2}$ Lissauer	$y = mx + b$ Howland and Dana
		Hours							
1	Wyda	6	117	Fasting, sleeping	5.649	1.94	23.67	26.97	26.51
2	Burke	6	115	Fasting, sleeping	6.724	1.46	20.43	23.07	22.78
3	O'Connor	27	127	Fasting, crying half of time	10.61	3.28	40.59	46.90	46.09
4	Wyda	31	110	Fasting, sleeping	6.255	2.22	26.54	30.66	29.90
5	Burke	31	119	Fasting, sleeping, few muscular twitchings	8.704	1.94	26.87	31.05	30.02
6	Barrett	72	119	Sleeping, cried out once	5.506	1.85	22.44	25.93	25.49
7	Wyda	80	117	Sleeping, few muscular twitchings	5.972	2.18	25.57	29.54	29.02
8	Burke	80	114	Sleeping, few muscular twitchings	7.101	1.66	22.67	26.19	25.43
9	Wyda	104	117	Sleeping, few muscular twitchings	5.252	1.83	21.85	25.25	24.82
10	Burke	104	109	Sleeping, cried at end	7.500	1.77	23.47	27.12	26.27
11	Wyda (moist air)	6th day	109	Sleeping, few muscular twitchings	5.616	1.95	23.37	27.00	26.54
12	Wyda (dry air)	8th day	109	Cried out few times	5.347	1.86	22.25	25.71	25.27
13	Burke (moist air)	8th day	120	Slept 34 minutes out of 85; cried 23 minutes	11.00	2.56	35.01	40.45	39.26
14	Burke (dry air)	8th day	115	Slept 65 minutes; cried 12 minutes	9.04	2.10	28.77	33.24	32.27
15	Knipe	8th day	115	Cried half of time	10.533	2.4	32.96	38.07	36.88
16	Soranto	9th day	122	Whimpered eight times; cried last 7 minutes	8.156	2.2	28.65	33.10	32.41
17	Knipe	10th day	122	Slept entire time	8.139	1.85	25.47	29.43	28.51
18	Knipe	11th day	(?)	Cried most of time	10.730	2.44	33.58	38.80	37.58
19	Knipe	12th day	126	Slept all but 17 minutes	8.817	2.05	28.02	32.37	31.41
				Mean of 12 sleeping periods, 4 infants	6.73	1.87	23.70	27.33	25.88
				Mean deviation from mean	....	±0.181	±1.60	±1.89	±1.77
				Mean deviation in percentage	....	9.6 %	6.7 %	6.9 %	6.8 %

age makes a measurable difference in both the newborn and older infants. Nevertheless it holds as a substantial statement of the facts that the metabolism of the young infant (two weeks to two months of age) on the basis of surface area is the same as that of an adult. By reference to Table 14, from Bailey and Murlin, it may be seen that the level of metabolism of the newborn less than one week of age is considerably lower than that of the adult. This discovery was made simultaneously by Benedict and Talbot, and Bailey and Murlin, though it was emphasized first by the latter authors. According to Meeh's formula the basal heat production of the newborn was 23.7 calories per square meter per hour.

Benedict and Talbot interpret their results on all their infants between birth and one week of age as showing no relation between body surface and metabolism. Yet when two extreme groups like those mentioned on page 587 are selected from their results, it is found that the average metabolism per unit of weight differs 12.5 per cent., while on the basis of surface area (Meeh's formula), the same groups show a difference of less than 3 per cent., namely, 24.1 and 23.4 calories per square meter per hour.*

The basal metabolism of the newborn above 12 hours of age while sleeping quietly at a comfortable temperature is in the neighborhood of 23 or 24 calories per square meter of surface, in contrast with that of the adult which is in the neighborhood of 32 or 33 calories. In other words, the metabolism of the newborn is nearly one-third less than that of the adult. On the same basis, the basal metabolism of the 31 newborn babies less than 12 hours of age in Benedict and Talbot's series is about 20 calories per square meter per hour or quite 40 per cent. less than that of the adult. Singularly enough this same level of metabolism may be reached by the adult after 20 days of fasting.[12]

The Different Formulæ for Surface Area.—There has been in recent years much discussion of the metabolism of infants in proportion to surface area; but there is no agreement as to which formula best represents the actual surface of the child or which will give values for surface most nearly proportional to the basal metabolism. In fact, the data available upon which such a comparison could be made are scarcely sufficient, even with the large addition recently made by the Nutrition Laboratory at Boston. It is worth while, however, to carry the study as far as the data will permit.

There are five formulæ in current use: (1) The old formula of Meeh[114] as modified by Rubner[162] for children, $11.9\sqrt[3]{(W)}^{2}$, which has been the reliance of most German writers; (2) the formula of Lissauer,[100] based upon independent measurements of 12 infants, most of them decidedly underweight, $10.3\sqrt[3]{(W)}^{2}$, and differing from Meeh's formula only in the size of the constant; (3) that of Howland and Dana,[87] based upon the old measurements of Meeh and Lissauer but given an entirely new form, namely, $y = mx + b$, where y is the surface in square centimeters, x is weight in grams, m a constant, 0.483, and b another constant 730; (4) the formula of DuBois,[50] $S = wt.^{0.425} \times ht.^{0.725} \times 71.84$; the weight being given in grams and the height in centimeters, the surface is found in square centimeters; (5) the so-called linear formula of DuBois,[51] which has been explained on page 541.

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* See further discussion of this point on p. 642.

Which of these formulæ most correctly represents the actual skin surface of the child it will be impossible to say until many more actual measurements are made. Meantime it is important to know which formula most nearly parallels the heat production for different children whether it correctly represents surface or not; for it is just conceivable that the actual surface might not be exactly proportional to basal metabolism because of the fact that certain portions of the skin must radiate heat much more rapidly than others. Furthermore, it is now well known that a considerable fraction of the heat[185] is lost through the lungs by evaporation of moisture in the breath.

Bailey and Murlin made a comparison (Table 14) of the basal metabolism per unit of surface as measured by the first three formulæ given above from the results obtained in 12 sleeping periods with four of their newborn infants. Employing the mean percentage deviation from the mean, they found that the formula of Meeh gave results only slightly less variable than those of Lissauer or Howland and Dana, the difference being quite negligible. A more satisfactory measure of variability is the mean standard deviation, and for correlation of two characters like heat production and body surface it is necessary to employ statistical methods. This will be taken up in the next section after which we may return to the discussion of surface area as a measure of metabolism.

Statistical Analysis of Basal Metabolism in Newborn Infants.—Harris and Benedict,[70] in their recent monograph entitled "A Biometric Study of Basal Metabolism in Man," have subjected the data concerning the minimal metabolism of newborn infants of the Boston series to statistical analysis, and have brought to light some new relationships. Since the statistical treatment of public health data is already familiar to the physician, and since physiological data are likely to be so treated* with greater frequency in the future, it may not be inappropriate to review briefly in this place the results of this analysis as applied to the newborn.

Most students of biological phenomena are inclined to stop before sufficient data are assembled or to be content with a cursory survey of their significance. As a matter of fact, a series of measurements, whether anatomical such as the circumference of the head, length of body, etc., or physiological such as vital capacity, oxygen absorption, etc., has no significance as a series until subjected to mathematical analysis of some degree or other. We make a beginning at such analysis when we determine the average measurement, such as average height or weight, or height-weight index for a given age. For many purposes this degree of analysis suffices; for it enables one to locate an individual measurement, pulse rate, temperature, or what not with reference to the mean of normal subjects. A distinct advance is made, however, if one knows not only the average of any supposedly normal series, but also the mean deviation from the average presented by the individuals of that series. Referring to Fig. 209, the mean is represented by a heavy black line. The individuals are scattered about the mean in approximately equal numbers above and below. Now it is clear that the same mean might apply also to another series in which the individuals had a wider scatter or dispersal, or indeed one in which they were closer together. It becomes significant, therefore, to know the average distance or deviation from the mean. Whether the individuals are representative or well chosen may often be learned in this way.

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* For a fuller statement of method, the reader is referred to Chapter II of Harris and Benedict's paper, or to Karl Pearson's Grammar of Science, or Davenport's Statistical Methods, 3rd edition, Chapters II and IV.

It is quite customary to express the mean deviation in percentage of the mean or average (Table 14, p. 590), and for most purposes this gives the desired information. It expresses in a way the degree of variability with which one has to deal. Thus one may say as the result of this simple mathematical analysis that *on the average* an individual measurement in a certain series will not be more than 10 per cent. away from the mean, while in another series it might be 20 per cent. away. Clearly, the former would be the more concordant series of observations.

For purposes of correlation, however, this analysis does not go far enough. If we wish to know whether heat production is correlated with pulse rate or whether it is more closely correlated with body-weight than with stature or with body surface, a different procedure must be adopted and a little algebra employed. A causal relationship between two factors, if the dependence is primary, could scarcely exist without exhibiting a definite mathematical relationship. There are times, of course, when the correlation may be obscured; and again the individuals of a series may be so poorly chosen as to cover up the primary dependence with interfering factors. The statistical analysis will often disclose this state of affairs, and lead to the detection of the interfering factor. For the present purpose it will suffice to develop the coefficient of variability and the coefficient of correlation.

The coefficient of variability is based upon what is known to the statistician as the standard deviation (S. D. or small sigma, σ). This term offers some distinct advantages over the mean deviation from the mean. It is obtained by squaring the individual distances or deviations from the mean, adding the squares, dividing by the number of individual deviations, and extracting the square root; or, in more condensed phraseology, it is the square root of the mean square deviation. One advantage consists in getting rid of the algebraic sign of the deviation. For purposes of correlation, *i.e.*, closeness of agreement, between two variables, we are not as a rule concerned about the individual measurement, whether it lies above or below the mean; hence its sign is of no interest. Moreover, even the arithmetical mean which must always read ± so and so does not give any information as to any individual in the series. It expresses nothing more than that the average distance from the mean is of such and such magnitude, whether above or below. Nothing is lost, therefore, by getting rid of the sign, which we do by squaring the deviation. Another and greater advantage consists in placing relatively greater significance upon a large deviation than upon a small one. Whether as a test of variability or as a criterion of correlation, the extreme variate is much more significant than a moderate one. The standard deviation takes account of this difference because the square of a large deviation has a greater influence than the square of a small deviation.

The formula employed for the standard deviation is

$$\sigma_x = \sqrt{\Sigma[(x-\bar{x})^2]/N}$$

where σ reads "the standard deviation of measurement x;" $\bar{x}$. is the mean of their measurement; $x - \bar{x}$ is the individual deviation; Σ their sum; and N their number.

Let us apply this concretely to a short series of weights of infants. In the following tables selected from Table 12 of Benedict and Talbot[23] paper on "The Physiology of the Newborn," the mean deviation from the mean is contrasted with mean square deviation, and below, the method of deriving the standard deviation is given. The

TABLE 15.—AVERAGE DEVIATION FROM THE MEAN CONTRASTED WITH STANDARD DEVIATION IN INFANTS TWO DAYS OLD (BENEDICT AND TALBOT)

Number	Weight in kilograms (w)	Deviation from mean ($w - \bar{w}$)	$(w - \bar{w})^2$
8	3.48	+0.15	0.0225
10	3.45	+0.12	0.0144
30	3.33	±0.0	±0.0
51	3.73	+0.40	0.1600
53	2.87	−0.46	0.2116
70	3.56	+0.23	0.0529
74	3.63	+0.30	0.0900
4	3.28	−0.05	0.0025
9	4.04	+0.71	0.5041
13	3.25	−0.08	0.0064
21	2.92	−0.41	0.1681
34	2.90	−0.43	0.1849
43	3.62	+0.29	0.0841
65	2.63	−0.70	0.4900

$$\underset{\underset{\text{Mean}}{\uparrow}}{\frac{\Sigma w}{N}, (\bar{w}) = 3.33} \qquad \underset{\underset{\text{Mean deviation}}{\uparrow}}{\frac{\Sigma(|w - \bar{w}|)^*}{N} = \pm\, 0.309} \qquad \underset{\underset{\text{Mean square deviation}}{\uparrow}}{\frac{\Sigma(w - \bar{w})^2}{N} = 0.1422}$$

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* The vertical bars indicate that the sum of the deviations is taken without regard to their signs.

$$\text{Mean percentage deviation } \Sigma(|w - \bar{w}|)/N \times \frac{100}{\bar{w}}$$

$$= \pm \frac{0.309 \times 100}{3.33} = \pm 9.3$$

$$\text{Standard deviation, } \sigma w, = \sqrt{\Sigma[(w - \bar{w})]^2/N} = \sqrt{0.1422} = 0.377$$

$$\text{Percentage standard deviation or } Vw = \frac{\sigma \times 100}{\bar{w}} = \frac{0.377 \times 100}{3.33} = 11.3$$

---

last term is called the coefficient of variability. It is simply the percentage of the mean (weight, in this case) which the standard deviation represents. All standard deviations may be so expressed and thereby made comparable one with another. The coefficient of variability, it will be noted, has lost its sign and is larger than the mean percentage deviation.

Suppose now we have two variables, weight an anatomical character, and heat production a physiological character: how may they be correlated? Repeating the same table, but with the addition of total heat production per hour, we shall see, first of all, which is the more variable, the anatomical or the physiological character.

TABLE 16.—COMPARISON OF VARIABILITY BETWEEN WEIGHT (w) AND HEAT PRODUCTION (h) IN INFANTS TWO DAYS OLD (BENEDICT AND TALBOT)

Number	Weight in kilograms (w)	Heat production in calories per hour (h)	$(w - \bar{w})$	$(w - \bar{w})^2$	$(h - \bar{h})$	$(h - \bar{h})^2$
8	3.48	6.66	+0.15	0.0225	+0.45	0.2025
10	3.45	6.75	+0.12	0.0144	+0.54	0.2916
30	3.33	6.00	±0.00	0.0000	−0.21	0.0441
51	3.73	6.41	+0.40	0.1600	+0.20	0.0400
53	2.87	5.95	−0.46	0.2116	−0.26	0.0676
70	3.56	6.37	+0.23	0.0529	+0.16	0.0256
74	3.63	6.50	+0.30	0.0900	+0.29	0.0841
4	3.28	5.79	−0.05	0.0025	−0.42	0.1764
9	4.04	7.42	+0.71	0.5041	+1.21	1.4641
13	3.25	5.75	−0.08	0.0064	−0.46	0.2116
21	2.92	5.67	−0.41	0.1681	−0.54	0.2916
34	2.90	5.58	−0.43	0.1849	−0.63	0.3969
43	3.62	6.87	+0.29	0.0841	+0.66	0.4356
65	2.63	5.29	−0.70	0.4900	−0.92	0.8464
Mean......	3.33	6.21	0.309	0.1422	0.492	0.3270

↓ ↓

Mean percentage deviation.. ±9.3 per cent...... ±7.8 per cent.

$$\text{Standard deviation of weight } \sigma w = \sqrt{\Sigma[(w - \bar{w})]^2/N}$$

$$= \sqrt{0.1422} = 0.377$$

Standard deviation of heat production $\sigma h = \sqrt{\Sigma[(h - \bar{h})]^2/N} = \sqrt{0.3270} = 0.572$

$$Vw = \frac{\sigma w \times 100}{\bar{w}} = \frac{0.377 \times 100}{3.33} = 11.3$$

$$Vh = \frac{\sigma h \times 100}{6.21} = \frac{0.572 \times 100}{6.21} = 9.2$$

From this comparison it is seen that in these infants of the same age, weight is 1.5 per cent. more variable than the heat production on the basis of the mean deviation, but is more than 2 per cent. more variable on the basis of the standard deviation.

The fact that the variability in the two series of measurements is relatively small does not, of necessity, mean that there is any correlation between the two series. The result so far indicates merely a relatively close concordance among the several observations of each series. Pursuing the comparison a little farther, however, we notice (Table 16) that the simple deviations from the mean have, without exception, the same sign. This denotes in general that when the weight is above the average the heat production is above the average and when the weight is below the average heat production is likewise. If, in addition, the magnitude of the deviations should appear to be of the same order for each individual, we could safely speak of a significant degree of correlation without further analysis.

In order to give the degree of correlation a quantitative value, however, we must proceed a little farther. If we multiply together the several deviations or distances from the mean in the two series, and get the mean of these products, this "mean product deviation," as it is called, will be high if nearly all the paired members of the two series of deviations have the same sign or if those which have the same sign are large in amount in comparison with those which have unlike signs. Here comes in especially the significance of the extreme variate; for if an individual is far out of the average as regards weight and is far out also as regards heat production, a close correlation between weight and heat production is indicated if the variate lies either above or below the mean in both characters; but a poor correlation is indicated if it is plus in one character and minus in the other. Multiplying the two together in either case will serve properly to evaluate the extreme variate. The mean product deviation, then, is itself a measure in absolute terms of the degree of correlation between any two characters, a high mean product denoting a close relationship and a low mean product a remote relationship between them.

In order to get the correlation upon a basis which will permit of its comparison with any other, it must be expressed in relative terms. That is to say, we must have a coefficient of correlation. This might be obtained by expressing the mean product deviation as a percentage of the product of the two standard deviations ($\sigma_w \sigma_h$, in this case) if we so desired, and perfect correlation would then be indicated if the result

TABLE 17.—CORRELATION BETWEEN WEIGHT (w) AND HEAT PRODUCTION (h) AND BETWEEN SURFACE (s) AND HEAT PRODUCTION IN INFANTS TWO DAYS OLD (AFTER BENEDICT AND TALBOT)

Number	Weight in kilograms (w)	Surface area in square meters			$(w - \bar{w})(h - \bar{h})$	$(h - \bar{h})(s - \bar{s})_M$	$(h - \bar{h})(s - \bar{s})_L$	$(h - \bar{h})(s - \bar{s})_D$
		(Meeh) s_M	(Lissauer) s_L	(DuBois)* s_D				
8	3.48	0.273	0.236	0.208	+0.0675	+0.00360	+0.00315	+0.00270
10	3.45	0.271	0.235	0.210	+0.0648	+0.00324	+0.00324	+0.00486
30	3.33	0.265	0.230	0.204	±0.0	±0.0	−0.00021	−0.00042
51	3.73	0.286	0.248	0.219	+0.0800	+0.00420	+0.00380	+0.00340
53	2.87	0.240	0.208	0.182	+0.1196	+0.00650	+0.00546	+0.00520
70	3.56	0.277	0.240	0.214	+0.0368	+0.00192	+0.00176	+0.00128
74	3.63	0.283	0.243	0.215	+0.0870	+0.00464	+0.00406	+0.00377
4	3.28	0.262	0.229	0.190	+0.0210	+0.00126	+0.00084	+0.00546
9	4.04	0.301	0.261	0.222	+0.8591	+0.04356	+0.03872	+0.02420
13	3.25	0.261	0.226	0.199	+0.0368	+0.00184	+0.00138	+0.00138
21	2.92	0.243	0.210	0.188	+0.2214	+0.01188	+0.01026	+0.00648
34	2.90	0.242	0.209	0.198	+0.2709	+0.01449	+0.01260	+0.00693
43	3.62	0.280	0.243	0.212	+0.1914	+0.00990	+0.00924	+0.00462
65	2.63	0.226	0.196	0.182	+0.6440	+0.03588	+0.03036	+0.00838
Mean.........	3.33	0.265	0.231	0.203	0.1928	+0.01021	+0.00890	+0.00558

$\sigma_w = 0.377$

$\sigma_h = 0.572$

$\sigma s_M = 0.020$

$\sigma s_L = 0.0174$

$\sigma s_O = 0.0129$

$$\gamma_{wh} = \frac{\Sigma[(w - \bar{w})(h - \bar{h})]/N}{\sigma_w \sigma_h} = \frac{0.1928}{0.377 \times 0.572} = 0.894$$

$$\gamma_{hs_D} = \frac{\Sigma[(h - \bar{h})(s - \bar{s}_M)]/N}{\sigma_h \, \sigma s_M} = \frac{0.01021}{0.572 \times 0.020} = 0.892$$

$$\gamma_{hs_L} = \frac{\Sigma[(h - \bar{h})(s - \bar{s}_E)]/N}{\sigma_h \, \sigma s_L} = \frac{0.00890}{0.572 \times 0.0174} = 0.894$$

$$\gamma_{hs_M} = \frac{\Sigma[(h - \bar{h})(s - \bar{s}_D)]/N}{\sigma_h \, \sigma s_D} = \frac{0.00558}{0.572 \times 0.0129} = 0.756$$

* This is the height-weight formula of DuBois.

were 100 per cent. Thus, if in the two series just considered the individual deviations of weight and heat production were of the same relative size in every pair, and always of the same sign, their product would be equal to the product of the square roots of the mean square deviations, and the result would be 100 per cent., or perfect, correlation. It is a little simpler if perfect correlation be expressed by unity and any correlation less than this by a decimal. Greater elasticity is thereby afforded, since minor degrees may be expressed by additional decimal places. The mean product deviation then may be divided by the product of the standard deviations, and a coefficient whose maximum would be unity, will be given. Thus:

$$\gamma wh = \frac{\Sigma[(w - \bar{w})(h - \bar{h})]/N}{\sigma_w \sigma_h}$$

The expression, γwh, is read "the coefficient of correlation between weight and heat production;" and the formula reads, "the sum of the products of the individual deviations of the two series divided by the number (or the mean product deviation), further divided by the product of the standard deviations."

In carrying out the operation we may as well include a third character, so that a comparison may be made in correlation between one and each of the other two. Since the other character of greatest interest in this connection is surface area, it will be added to the next table. We have then two anatomical characters, weight and surface area, to be correlated with one physiological character; namely, heat production. If one or the other of these shows a closer correlation than the other, we may infer, other things equal, that it is more likely to be causally related to heat production.

It is seen that the correlation between weight and heat production for this particular group of infants is closer than between heat production and body surface, if the latter is calculated by the formula of Meeh or of DuBois, but if calculated by the formula of Lissauer the correlation is the same as with body weight. This must not be accepted as typical for all infants, however, for as we shall see presently a larger number of infants show very little difference in the correlation between heat production and body surface on the bases of the several formulæ. The group presented in the foregoing was selected as being as nearly homogeneous as possible, and was purposely kept small merely for the purpose of illustrating the method of statistical correlation.

It is necessary to delay further discussion of the relation of heat production to body surface for a moment, to take up the matter of probable error. Every determination of the mean of a series of observations is only an approximation to the truth, for a larger number of observations always will change it one way or the other; still more is this the case with constants where longer calculations based upon more factors enter. It is possible, however, to tell the measure of unreliability by means of the probable error, and it should always accompany a determination such as the standard deviation or the correlation between series of measurements. The probable error E is a number which, added to or subtracted from, the determined constant gives a pair of values between which the true value lies. It therefore is always expressed as ±. The probability that the determined constant (*e.g.*, mean) is correct is not directly proportional to the number of observations, but is nearly inversely porportional to the square root of the number. The probable error of the standard deviation is found[45] by the formula, $\frac{0.6745(\sigma)}{\sqrt{2n}}$ where n is the number of variates. In the several standard deviations just derived, the probable errors are given as follows:

$$\sigma\omega = 0.377 \pm \frac{(0.6745)(0.377)}{\sqrt{28}} = 0.377 \pm 0.0480$$

$$\sigma_h = 0.572 \pm \frac{(0.6745)(0.572)}{\sqrt{28}} = 0.572 \pm 0.0729$$

$$\sigma_{s_M} = 0.020 \pm \frac{(0.6745)(0.020)}{\sqrt{28}} = 0.020 \pm 0.0025$$

$$\sigma_{s_L} = 0.0174 \pm \frac{(0.6745)(0.174)}{\sqrt{28}} = 0.0174 \pm 0.0020$$

$$\sigma_{s_D} = 0.0129 \pm \frac{(0.6745)(0.129)}{\sqrt{28}} = 0.0129 \pm 0.0016$$

These probable errors signify that there is an even chance that the true value of the standard deviation in each case lies between these values. As compared with the standard deviations themselves, the probable errors are of the order of one-eighth, or we can say that the standard deviation is nearly eight times its probable error. The practical value of the probable error is in making comparisons of different constants, and may be illustrated in the examples before us in comparing the standard deviations from the mean of the surface areas as computed by the Lissauer and Meeh formulæ.

Comparing $\sigma_{s_M} = 0.020 \pm 0.0025$

and $\sigma_{s_L} = \underline{0.0174 \pm 0.0022}$

we find the difference is 0.0026 ± 0.0034*

In other words, the difference is no greater than its probable error and is therefore of no significance.

"In the case of correlations an apparently, but not essentially, different problem presents itself. One often desires to know whether there be any relationship at all between variables. He then inquires whether an empirically found value of the correlation coefficient has a 'significant' value. This is necessary because of the fact that if correlations were based upon small series of individuals drawn at random from an infinitely large series in which the correlations were zero, a *numerical value* would in many instances be obtained. This is true for the same reason that a small number of determinations of basal metabolism on a group of febrile patients would show an average value differing from that obtained on a small group of normal subjects whether there be any real influence of fever on metabolism or not.[70]" For example, the authors just quoted show that the correlations between stature and pulse rate in 121 men is $+ 0.0916 \pm 0.0608$ while for 90 women it is—0.0669 ± 0.0708. These constants differ from zero by 1.51 and 0.94 respectively, times their probable errors, and consequently could not be accepted as proving any real positive correlation between stature and pulse rate in the case of men as a class, or any real negative correlation in women as a class.

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* The square root of the sum of the squared probable errors. *Cf.* Davenport, *loc. cit.*, p. 15.

The probable error of the coefficient of correlation (E_γ) is given by the formula:

$$E_\gamma = \frac{0.6745\,(1 - \gamma^2)}{\sqrt{n}}$$

Hence the coefficients of correlation given above should be followed by probable errors as follows:

$$\gamma wh = 0.894 \pm \frac{0.6745\,(1 - 0.894^2)}{\sqrt{14}} = 0.894 \pm 0.0362$$

$$\gamma hs_M = 0.892 \pm \frac{0.6745\,(1 - 0.892^2)}{\sqrt{14}} = 0.892 \pm 0.0358$$

$$\gamma hs_L = 0.894 \pm \frac{0.6745\,(1 - 0.894^2)}{\sqrt{14}} = 0.894 \pm 0.0362$$

$$\gamma hs_D = 0.756 \pm \frac{0.6745\,(1 - 0.756^2)}{\sqrt{14}} = 0.756 \pm 0.0772$$

The ratio of the coefficient to its probable error γ/E_γ in each case is:

$$\gamma wh/E_{\gamma_{wh}} = 24.7$$

$$\gamma hs_M/E_{\gamma h_{sM}} = 24.6$$

$$\gamma hs_L/E_{\gamma h_{sL}} = 24.7$$

$$\gamma hs_D/E_{\gamma h_{sD}} = 9.8$$

The constants differ from zero by a significant number of times their probable errors and the higher their correlation coefficients the smaller (relatively) are their probable errors.

Surface Area as a Measure of Metabolism.—Only when a much larger number of observations on infants becomes available will it be possible to learn whether the same formula for surface area may properly be employed for newborns and for older infants, or whether there is an actual change in the physiological significance of surface as a factor in heat regulation as the infant grows older. Meantime it will be useful to make a comparison of the coefficients of correlation between basal metabolism and surface as measured by the several formulæ on the longest series of observations on newborns now available. The

Boston series contains 94 infants, 31 of whom were under 12 hours of age, 10 from 12 to 24 hours, 14 two days of age, 13 from four to five days, and so on up to a single infant seven days old. Taking the 94 all together, the writer has found the several coefficients of variability and of correlation to be as shown in the table below:

Coefficients of Variability

$V_h = 15.37 \pm 0.79$

$V_w = 14.68 \pm 0.72$

$V_{s_M} = 9.92 \pm 0.48$

$V_{s_L} = 10.08 \pm 0.49$

$V_{s_H} = 10.25 \pm 0.50$

$V_{s_D} = 8.84 \pm 0.43$

Coefficients of Correlation

$\gamma_{h\,w} = 0.7630 \pm 0.0205$

$\gamma_{hs_M} = 0.7672 \pm 0.0202$

$\gamma_{hs_L} = 0.7762 \pm 0.0195$

$\gamma_{hs_H} = 0.7677 \pm 0.0202$

$\gamma_{hs_D} = 0.7682 \pm 0.0202$

There are two surprises in this table: One, that heat production as determined by the method of Benedict and Talbot, is more variable than either body-weight or body surface, no difference by which formula it is measured; and the other, that it makes very little difference which formula is used for body surface so far as correlation with basal metabolism is concerned. The formula of Howland and Dana gives the most variable body surface; the height-weight formula of DuBois and DuBois the least variable. But the formula of Lissauer gives a body surface which parallels basal metabolism *slightly* better than the others, the difference, however, being altogether negligible.

As Murlin and Hoobler had already shown in older children, it is seen here that body-weight and body surface are almost equally valuable as measures of the basal metabolism. Harris and Benedict[70] reach this conclusion also from the use of body surface by Lissauer's formula and body-weight as bases of prediction of the basal metabolism of these same infants in comparing the metabolism as actually measured with that computed from constants based on the entire series. They note deviations of the predicted metabolism from that actually measured, as follows:

Average deviations with regard to sign	Boy babies, calories	Girl babies, calories
Prediction from weight..................	−0.020	−0.093
Prediction from surface..................	+0.118	+0.047

By this criterion surface area is slightly better than body-weight for girl babies but slightly worse for boy babies.

The correlation coefficients between basal metabolism and the anatomical characters thus far considered are not very high, but are of the same order as those found by Harris and Benedict for adults. There is no basis upon which to affirm that basal metabolism is more or less nearly proportional to body-weight or to body surface in infants than in adults.

The correlation coefficients between basal metabolism and weight for male and female infants, according to Harris and Benedict, are:

51 males.............................. $\gamma_{wh} = 0.7520 \pm 0.0411$
43 females.............................. $\gamma_{wh} = 0.8081 \pm 0.0357$

Difference.............................. 0.0561 ± 0.0544

Since the probable error of the difference is as large as the difference itself, the latter is not statistically significant, which means that the correlation is no better for girl babies than for boy babies. By use of regression formulæ, the authors show that in both male and female babies a difference of 100 gm. in weight between two subject or as growth of this amount in the same subject within the age limits considered would make a probable difference of 3.4 calories in the daily basal metabolism. This rate of increase is represented graphically in Fig. 210. The means smoothed and represented by straight lines for the two sexes lie very close together.

Relation of Body Length to Basal Metabolism.—The only investigators thus far to lay special stress upon stature in relation to the metabolism of infants are Benedict and Talbot.[23] Plotting their results on the basis of surface, it was noted that there was a tendency for shorter infants to exhibit a lower heat production per unit of surface than larger infants, and when this relationship was studied farther it developed that a closer concordance was obtained by a formula in which body length in addition to surface (derived from weight alone) was included. For some 40 infants between one and one-half and six days

TABLE 18.—BODY SURFACE COMPUTED FROM THE LISSAUER FORMULA ($10.3\sqrt[3]{(w^2)}$)
(BENEDICT AND TALBOT[23])

Body-weight, kilograms	Body surface, square meters	Body-weight, kilograms	Body surface, square meters	Body-weight, kilograms	Body surface, square meters	Body-weight, kilograms	Body surface, square meters
2.00	0.163	2.80	0.205	3.55	0.239	4.30	0.272
2.05	0.166	2.85	0.207	3.60	0.241	4.35	0.274
2.10	0.169	2.90	0.210	3.65	0.244	4.40	0.277
2.15	0.172	2.95	0.212	3.70	0.246	4.45	0.279
2.20	0.174	3.00	0.214	3.75	0.249	4.50	0.281
2.25	0.177	3.05	0.217	3.80	0.251	4.55	0.283
2.30	0.179	3.10	0.219	3.85	0.253	4.60	0.285
2.35	0.182	3.15	0.222	3.90	0.255	4.65	0.287
2.40	0.184	3.20	0.224	3.95	0.257	4.70	0.289
2.45	0.187	3.25	0.226	4.00	0.260	4.75	0.291
2.50	0.190	3.30	0.228	4.05	0.262	4.80	0.293
2.55	0.192	3.35	0.231	4.10	0.264	4.85	0.295
2.60	0.195	3.40	0.233	4.15	0.266	4.90	0.297
2.65	0.197	3.45	0.235	4.20	0.268	4.95	0.299
2.70	0.200	3.50	0.237	4.25	0.279	5.00	0.301
2.75	0.202						

of age, the metabolism was represented with a plus or minus deviation from the mean of only 6 per cent. by the formula $L \times 12.65 \times 10.3\sqrt[3]{(w)^2}$, where L is body length in centimeters. The authors give tables from which it is possible to calculate the metabolism with a probability that it will fall within the variability just mentioned. Table 18, reproduced from their monograph[23] (Table 15, p. 110), gives the surface area by the Lissauer formula for infants weighing between 2 and 5 kg. Table 19 contains the basal heat production per square meter of body surface (Lissauer) for each height from 45 to 55 cm. Knowing net weight in kilograms and height in centimeters, the surface is found by reading opposite weight in the first table, and this surface is multiplied by the metabolism per unit of surface found opposite the body length in the other table.

TABLE 19.—HEAT VALUES (PER SQUARE METER PER 24 HOURS) COMPUTED FOR VARYING LENGTHS (INFANTS ONE AND ONE-HALF TO SIX DAYS OLD INCLUSIVE) (BENEDICT AND TALBOT)[23]

Length, centimeters	Length × constant (12.65) calories	Length, centimeters	Length × constant (12.65) calories	Length, centimeters	Length × constant (12.65) calories
45.0	569	48.5	614	52.0	658
45.5	576	49.0	620	52.5	664
46.0	582	49.5	626	53.0	670
46.5	588	50.0	633	53.5	677
47.0	595	50.5	639	54.0	683
47.5	601	51.0	645	54.5	689
48.0	607	51.5	651	55.0	696

Body-weight and stature have independent significance in determining the basal metabolism of adults,[70] and from what has just been said it appears that the same must be true of infants. This would mean that of two children having the same weight (and therefore the same surface, by Meeh, Lissauer, or Howland's formula), the taller would show the higher metabolism.

The correlation coefficients between basal heat production and stature for male and female babies[70] are:

51 males........................	γ_{sh}	$= 0.6191 \pm 0.0582$
43 females........................	γ_{lh}	$= 0.7426 \pm 0.0461$
Difference........................		0.1235 ± 0.0719

Again, the probable error of the difference being so nearly equal to the difference itself, the two coefficients may be regarded as identical.

Disregarding sex the correlation coefficients of the entire group of 94 infants for stature and weight are found to be:

γ_{wh} . . . . $= 0.7833 \pm 0.0269$
γ_{lh} . . . . $= 0.6848 \pm 0.0369$

Difference . . . . 0.0985 ± 0.0457

Here the difference is a little larger in comparison with its probable error and we may infer that weight is a slightly better measure of basal metabolism than stature.

By the use of regression equations it is found that 1 cm. increase in length makes a difference of 8 to 10 calories in the total basal metabolism for 24 hours. This rate of increase is shown in Fig. 211 after Harris and Benedict.[70] The rate is not identical, though very nearly so, for male and female babies.

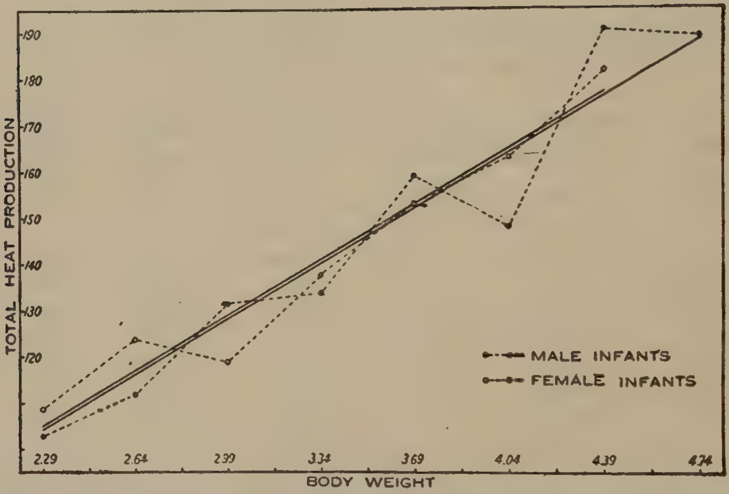

FIG. 210.—Mean basal metabolism on basis of 24 hours for male and female infants of various body weights. (Harris and Benedict, Carn. Inst. Publ. #279, 1919, Diagram 12, p. 90.)

Influence of Sex on Basal Metabolism.—From the sections immediately preceding, it is already evident that sex at this early age exercises little, if any, specific influence. Further examination confirms this impression. Thus the group of 31 infants under 12 hours of age in the Boston series includes 17 males and 14 females. The average weight of the males is 3.76 kilogram and they have an average metabolism per kilogram and hour of 1.53 calories. The average weight of the females is 3.29 kilogram and they have an average metabolism per kilogram and hour of 1.61 calories. The metabolism of the larger body is slightly less as before. The two groups, however, have exactly the same metabolism per unit of surface.

Carrying the comparison to older groups, we find the same is true of all infants two days of age. There are seven boys and seven girls

TABLE 20.—MINIMAL METABOLISM OF INFANTS TWO DAYS OF AGE (Compiled from Benedict and Talbot)[23]

Number	Weight, kilograms	Height, centimeters	Heat production per 24 hours	Heat production per kilogram and hour	Deviation from mean, per cent.	Surface area (Meeh)	Heat production per square meter and hour	Deviation from mean, per cent.	Surface area, DuBois formula*	Heat production per square meter and hour	Deviation from mean, per cent.
Males											
8	3.48	51.0	160	1.91	3.2	0.273	24.4	3.8	0.208	32.0	4.2
10	3.45	52.0	162	1.91	3.2	0.271	24.8	5.5	0.210	32.1	4.5
30	3.33	51.0	144	1.80	2.7	0.265	22.6	3.8	0.204	28.7	6.5
51	3.73	52.5	154	1.72	7.0	0.286	21.9	6.8	0.219	29.3	4.5
53	2.87	47.5	143	2.07	12.0	0.240	24.7	5.1	0.182	32.7	6.5
70	3.56	51.0	153	1.79	3.2	0.277	23.0	2.1	0.214	29.7	3.2
74	3.63	52.0	156	1.79	3.2	0.283	23.0	2.1	0.215	30.2	1.6
Average.......	3.43	51.0	153	1.85	±4.9	0.271	23.5	±4.1	0.207	30.7	±4.4
Females											
4	3.28	46.5	139	1.72	8.0	0.262	22.0	5.1	0.190	30.4	0.0
9	4.04	51.0	178	1.83	2.0	0.301	24.6	6.0	0.222	33.4	6.2
13	3.25	50.0	138	1.77	5.3	0.261	22.0	5.1	0.199	28.9	4.9
21	2.92	50.0	136	1.94	3.7	0.243	23.3	0.4	0.188	30.1	0.9
34	2.90	50.5	134	1.92	2.9	0.242	23.1	0.4	0.198	28.2	7.2
43	3.62	50.0	165	1.90	1.6	0.280	24.5	5.5	0.212	32.5	6.9
65	2.63	49.0	127	2.01	7.5	0.226	23.3	0.8	0.182	29.1	4.1
Average.......	3.23	49.5	145	1.87	±4.4	0.259	23.2	±3.3	0.196	30.4	±4.3

*The height-weight formula.

of this age in the Boston series. The average metabolism of the boys is 1.85 calories per kilogram and hour, while that of the girls is 1.87 calories. The average metabolism per unit of surface (Meeh) is 23.5 calories for the boys and 23.2 for the girls. Using the DuBois height-weight formula and calculating the surface, the average for the boys is 30.7 calories and for the girls 30.4 calories. The mean percentage deviation from the average is slightly less for both groups on the basis of the Meeh formula than it is on the basis of weight or on the basis of the surface as estimated by the DuBois formula.

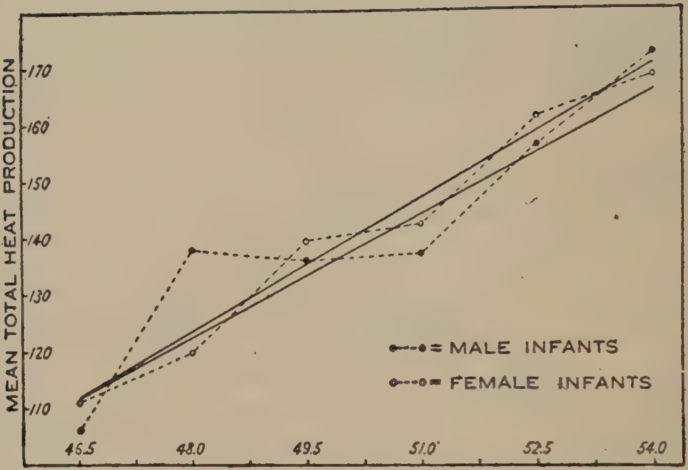

FIG. 211.—Mean basal metabolism on basis of 24 hours for male and female infants classified according to stature. (Harris and Benedict, Carn. Inst. Publ. #279, Wash., D. C., 1919, Diagram #13, p. 92.)

Going on to infants four to five days of age, in the same series, we find the average weight of the boys is 3.34 kg., that of the girls 3.83. The basal heat production per kilogram and hour of the former is 1.88; that of the latter 1.83 calories. On the basis of the Meeh formula the basal metabolism of the boys per square meter of surface is 23.5 calories and that of the girls 23.2. On the basis of the DuBois formula the metabolism is 30.5 and 31.0 calories per square meter per hour respectively. The mean deviation from the average is again less for the Meeh formula (Table 21).

In the statistical analysis of the basal metabolisn of the entire Boston series, Harris and Benedict carried the comparison somewhat farther. They predicted the metabolism of girl infants from constants based on the boys, and determined the sign and magnitude of the difference between observed and calculated values. Equations employed were those showing regression of basal metabolism on stature (body length), on weight, and on body surface in the male infants. Subdividing the entire series of female infants into stature groups, it was found that out of six groups three showed a higher metabolism and

TABLE 21.—MINIMAL METABOLISM OF INFANTS FOUR TO FIVE DAYS OF AGE (Compiled from Benedict and Talbot)

Number	Weight, kilograms	Height, centimeters	Heat production per 24 hours	Heat production per kilogram and hour	Deviation from mean, per cent.	Surface area (Meeh)	Heat production per square meter and hour	Deviation from mean, per cent.	Surface area, DuBois formula	Heat production per square meter and hour	Deviation from mean, per cent.
						Males					
15	3.64	50.0	162	1.85	1.6	0.281	24.0	2.1	0.209	32.3	5.8
25	3.32	51.5	158	1.98	5.3	0.264	24.8	5.5	0.212	32.5	6.5
27	3.58	52.0	169	1.96	4.2	0.278	24.7	5.1	0.217	32.4	6.2
31	3.56	53.5	158	1.85	1.6	0.277	23.7	0.8	0.221	29.8	2.3
33	3.73	52.0	153	1.71	9.0	0.286	22.3	5.1	0.218	29.2	4.2
56	3.19	51.5	150	1.96	4.2	0.278	24.7	5.1	0.217	32.4	6.2
60	3.60	52.0	149	1.72	8.5	0.279	22.2	5.5	0.217	28.6	6.2
68	2.12	46.0	103	2.02	7.4	0.196	21.8	7.2	0.159	27.0	11.4
Average.......	3.34	51.0	150	1.88	±5.2	0.267	23.5	±4.5	0.209	30.5	±6.1
						Females					
12	4.17	52.5	171	1.70	7.1	0.302	23.1	0.4	0.211	33.7	8.7
26	3.46	50.0	150	1.80	1.6	0.272	22.9	1.3	0.204	30.5	1.6
35	4.33	54.0	175	1.68	8.1	0.316	23.1	0.4	0.238	30.6	1.3
40	2.78	49.5	134	2.00	9.3	0.235	23.7	2.1	0.185	30.1	2.9
49	2.75	47.5	130	1.97	7.6	0.233	23.2	0.0	0.179	30.2	2.6
Average.......	3.83	50.7	152	1.83	±6.7	0.271	23.2	±0.8	0.203	31.0	±3.4

three a lower metabolism than that predicted on the assumption that all were boys of like height. Classifying by surface area, out of seven groups four showed a higher metabolism and three a lower than predicted on the assumption that they were boys with the surface area of the girls. The comparison for body-weight turned out the same. The authors conclude: "As far as our data go, they indicate that on the average there is no sensible difference between the heat production of the two sexes in the first week of life."[70]

Influence of Crying.—Since the newborn child is scarcely able to influence metabolism by any other form of muscular effort than crying, the activity factor may be discussed under this heading. Bailey and Murlin cited among their results the case of a child 10 days of age who produced 8.14 calories per hour while sleeping quietly throughout the period of observation. The next day, while crying "most of the time," *i.e.*, one hour, she produced 10.73 calories, an increase of 31 per cent. Howland observed an increase of 39 per cent. in an infant seven months of age for a one-hour period of "struggling and crying." Benedict and Talbot have contrasted in one of their tables minimal with maximal periods of activity (including crying) for 93 infants, and deduce an average difference of 65 per cent., the individual differences ranging from 4 to 211 per cent.! Unfortunately 65 out of the 93 maximal periods "are calculated from the carbon dioxide produced during a preliminary period for which the respiratory quotient was not determined." Since even those periods for which oxygen as well as carbon dioxide was determined oftentimes gave "defective respiratory quotients due to excessive carbon dioxide excretion—or to a defect in the measurement of the oxygen, particularly the residual oxygen[23]" it is impossible to compare Benedict and Talbot's results with those of Howland or Bailey and Murlin whose "crying" periods, like their basal periods, were controlled by residual analyses. From a practical point of view, however, namely the effect of crying upon the energy requirement of the newborn, the several authors are in substantial agreement. For an infant who cries no more than the average normal infant, probably 30 per cent. increase above the basal would more than cover the energy requirement for maintenance; while for an infant who cries "most of the time" (admitting considerable latitude in the use of the expression), probably 40 per cent. above the basal would be more than adequate; for it is certain that no newborn infant can continue to cry at a rate sufficient to increase the metabolism 40 per cent. for more than a few hours out of the 24.

More light on this subject will be gained when we have a method of recording the muscular activity which will make one period quantitatively comparable with another and one child also comparable with another. Attempts have been made to accomplish this purpose by means of a pneumographic record, a record produced by air transmission directly from the bed contained in the respiration apparatus, constructed as a receiving tambour, and by means of a record of the movements of the bed suspended at one end from a helical spring (p. 562). But the graphs obtained by these methods are not strictly comparable on account of variations in the distensibility of certain elastic parts. Benedict and Talbot, in fact, expressly warn the reader that their classification of the degree of muscular repose (four different degrees made from the graphic records independently by two skilled observers) is not intended as a comparison of the activity of one infant with another. The principle of the work Adder* calibrated in absolute terms will doubtless prove more satisfactory in time.

The Pulse as a Measure of Muscular Activity.—Because the pulse rate increases with muscular activity, some students of metabolism not very familiar with the physiology of the circulation have insisted upon its value as a criterion of internal muscular activity and even as a measure of metabolism. If the heart of a given individual always discharged the same volume of blood beat after beat, there would be some rational basis for this use of the pulse rate, for its numerical value would then be a direct measure of the volume output of the left ventricle, and this in turn, since the arterial blood is practically always saturated with oxygen, would be a measure within moderate limits at least of the oxygen supply† to the tissues at different times for this individual. But it is well known that the ventricular output may vary enormously[123] in the same individual, depending upon venous pressure, arterial pressure, cardiac tonus, and perhaps other factors.[204] Much more is this true, for obvious reasons, of different individuals. Confirmation of this position, which the writer has maintained for many years, is found in the biometric study by Harris and Benedict.[70] Correlations between pulse rate and total heat production (basal metabolism) are "all positive in sign but numerically low and extremely variable in magnitude." The statement applies to adults. The data for newborn infants were at hand but for some reason the authors did not carry their study of correlations with pulse rate in this series beyond body-weight and stature. The omission is corrected herewith. The coefficient of variability for pulse rate is fairly near that for surface

$$\sigma_p = 9.39 \pm 0.461$$

$$V_p = \frac{\sigma \times 100}{\bar{p}} = 8.3 \text{ per cent.} \pm 0.411 \text{ per cent.}$$

$$\gamma_{hp} = 0.276 \pm 0.643$$

area by the different formulæ, (p. 604), and one might suppose that the coefficient of correlation with basal metabolism also would be high. The reverse proves to be true. The coefficient is positive, but very low, and in comparison with its probable error, so low as to indicate total absence of correlation.

Body Temperature and Basal Metabolism.—In their monograph on the physiology of the newborn, Benedict and Talbot[23] state that their observations "indicate that there is a distinct correlation between the body temperature of the infant and the total metabolism, for on the days with low body temperature the total metabolism was likewise low." It will be remembered that "total metabolism" as used by these authors really means basal metabolism calculated on the 24-hour basis. The term "correlation," however, is here used very loosely, for it turns out on applying the statistical analysis that body temperature is scarcely better as a criterion of basal metabolism than is pulse rate. The coefficients as computed by the writer from the fundamental data in the Boston series[23] of newborns are as follows:

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* As used with the spirometer on the clinical calorimeter at Bellevue Hospital.

† Not, however, of the oxygen consumed; for this is found only by analysis of the venous blood and subtraction of the oxygen there found from arterial oxygen.

$$\sigma_t = 0.319 \pm 0.154$$

$$V_t = \frac{\sigma \times 100}{\bar{t}} = 0.86 \text{ per cent.} \pm 0.42 \text{ per cent.}$$

$$\gamma_{ht} = 0.439 \pm 0.561$$

Body temperature is scarcely variable at all (0.86 per cent.) as compared with basal metabolism (15.37 per cent.). The coefficient of correlation is somewhat higher than that for pulse rate but is not statistically significant as shown by the size of its probable error. This conclusion from Benedict and Talbot's data is in accord with that of Hasselbalch[71] from his own, who says, "the infant's body temperatures during the experiments do not show large differences, and these are in all instances plainly not parallel with the differences in the amount of the metabolism." Instead of being a criterion of basal metabolism in any quantitative sense, body temperature must therefore continue to be merely a symptom. Often it is low and often high coincidentally with metabolism, but *body temperature is a resultant* of which heat production is only one of the important factors. Rate of heat loss can affect body temperature quite as much as rate of production.

Influence of Food and External Temperature.—Very few observations have been made indicating that the food of the newborn has any dynamic effect. Hasselbalch reports two observations on premature infants (Nos. 15 and 16 in Table 9) in which he surmises that the increase of some 15 per cent. in metabolism the second period is due to the "work of digestion." "At any rate," he asserts, "it was impossible to recognize a difference in the muscular activity of the infant." Since the first effect of hunger is to induce muscular activity in the form of crying, it is very difficult to secure complete muscular repose on empty stomach so as to have a basis of comparison with periods following the ingestion of food. In Hasselbalch's comparison just cited both periods follow the feeding and the more active work of digestion in the second period is inferred from the higher respiratory quotient.* Coupled with the difficulty just mentioned is the natural reluctance of the physician to give the newborn a large feeding. In fact it is quite possible that the stomach of the child at this time cannot contain enough food at a single filling to raise the metabolism sensibly.

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* Discrepancy between the notes in the table and the facts as stated in the text makes the experiment impossible of exact interpretation.

We are equally without convincing evidence that external temperature acting independently can influence metabolism in the newborn. Scherer[170] reported a difference of 23 per cent. in oxygen absorption by the infant between what he called summer temperature (16 to 26. 8°C.) and winter temperature (9.5 to 16.2°C.). But there was no control of muscular activity, or even notes regarding crying. Hasselbalch conducted his experiments at an average temperature of about 33°C; Bailey and Murlin maintained a temperature of 27 to 29°C; while Benedict and Talbot kept their chamber air at approximately 20°C. Hasselbalch is deeply impressed with the fact that his newborn infants (most of them only a few hours from birth) produced only 270 c.c. of carbon dioxide per kilogram and hour and that "this is not essentially higher than the corresponding figure for a grown individual in absolute repose." From the connection in which the author alludes to this comparison one might infer that the low temperature which he mentions was due to the absence of all "chemical regulation" since the temperature was "so regulated that the question of the feeble heat regulation of the infant is eliminated as far as possible." Results even lower than this, however, may be seen in several instances amongst the data reported in the more recent publications, notwithstanding the lower temperatures employed. A careful scrutiny of the several tables has failed to reveal any relationship between external temperature and the metabolism recorded. Doubtless the infants in the several series of observations were wrapped in different quantities of clothing and bedding necessary to maintain an environmental temperature high enough to induce quiet sleep which was always the aim. Since the notes with reference to this precaution are not very complete, it will be necessary to give special attention to clothing before any final judgment as to influence of external temperature can be rendered.

Crying the Chief Factor.—In conclusion of this discussion of the factors which may influence heat production in the newborn, emphasis should be placed once more upon the fact attested to by several observers that crying is the only normal form of activity which can materially raise the metabolism above the basal level. In the words of our Danish colleague, "as regards the amount of the metabolism, it seems impossible for me to conclude anything else from the tables than that the activity of the infant is the chief determining factor." Hasselbalch goes on to say that even the influence of age has not been demonstrated (in the newborn). While sanction can not be given to this statement since the publication of Benedict and Talbot's results, (p. 588), emphatic assent can be given to his estimate of the muscular factor. The newborn does not shiver. He responds, however, to a drop in external temperature, as he does to hunger, very promptly, by crying, and since this form of exercise is almost his only resort, it serves at once the double purpose of restoring heat production to an equality with heat loss and of calling the attention of his nurse to his unhappy plight. The importance of conserving the energy resources of the newborn infant by keeping him warm, especially before his natural food is forthcoming, is obvious.

Total Energy Requirement of the Newborn.—If the feeding of infants is ever to be placed upon a rational basis and not remain a matter largely of guess work, it is necessary that the normal requirements of the newborn be definitely established. Thus far we have considered the basal metabolism *i.e.*, the metabolism of the sleeping infant and have learned that body weight is nearly, if not quite, as good a measure as body surface, and that length of body (stature) combined with surface (or weight) gives possibly the best measure now available. The newborn up to one week of age requires for maintenance while asleep 1.87 calories per kilogram and hour or about 25 calories per square meter of body surface (Meeh). On the 24-hour basis this becomes 45 calories per kilogram or 600 calories per square meter of body surface. The formula of Benedict and Talbot ($L \times 12.65 \times 10.3 \sqrt[3]{w^2}$) *i.e.* length in centimeters times a constant times the body surface, as given by Lissauer's formula, is a slightly closer approximation to the average needs. There is a normal variation from this standard of 6 per cent., due to factors (possibly endocrine index) not yet understood. The basal requirement for a given infant within these limits may be read off the table on page 603.

For the time during which the infant is awake and crying, the requirement, as nearly as it can be estimated today, is from 30 to 40 per cent. higher. Since, however, the period of crying continues for the normal newborn rarely more than a few hours at most, the additional allowance of food energy should not be computed on a 24-hour basis, but an attempt should be made to estimate the total period of crying.

The energy allowance for growth can not yet be estimated with any accuracy. In general it may be stated only that any energy left over after the basal and activity metabolism are provided for will be available for growth, since, so far as we can see at present, no allowance is necessary for dynamic action or for fluctuations of external temperature.

It would appear from the foregoing that an energy supply of 2.5 calories per kilogram per hour or 60 calories per kilogram and 24 hours, will amply cover the maintenance requirement of newborn infants who are not more than normally active. Any intake beyond this amount may, it is presumed, be counted upon to furnish materials for growth. Further study of the "growth quota" in infants of this age, however, is very much needed. Further discussion of this topic will be deferred to the section dealing with the metabolism of infants up to one year of age.

Loss in Weight of the Newborn.—Before considering the possibility of supplying to the newborn a full energy requirement to cover basal metabolism, activity metabolism, and growth, the loss in weight which is characteristic of the first week of postnatal life for the human offspring must be examined. Among the causes of loss, certainly, are the passage of meconium, urine, and at times allantoic fluid regurgitated from the stomach. Until food is administered there is, of course, loss of organic materials which supply energy by combusion. But most important of all is the loss of water. Birk and Edelstein [28] examined a newborn baby in a Voit-Pettenkofer apparatus determining the carbon dioxide elimination and the water loss. They recorded 28.12 gm. of water as coming from the infant's body and evaporated into the air the first 12 hours and 40.74 and 53.6 gm. respectively for the next two periods of 24 hours each. Most of this water comes from the skin and lungs. Lust[107] studied the concentration of dry substances in the blood the first week as compared with subsequent periods and found, as he believed, a close relationship between body weight and dilution of the

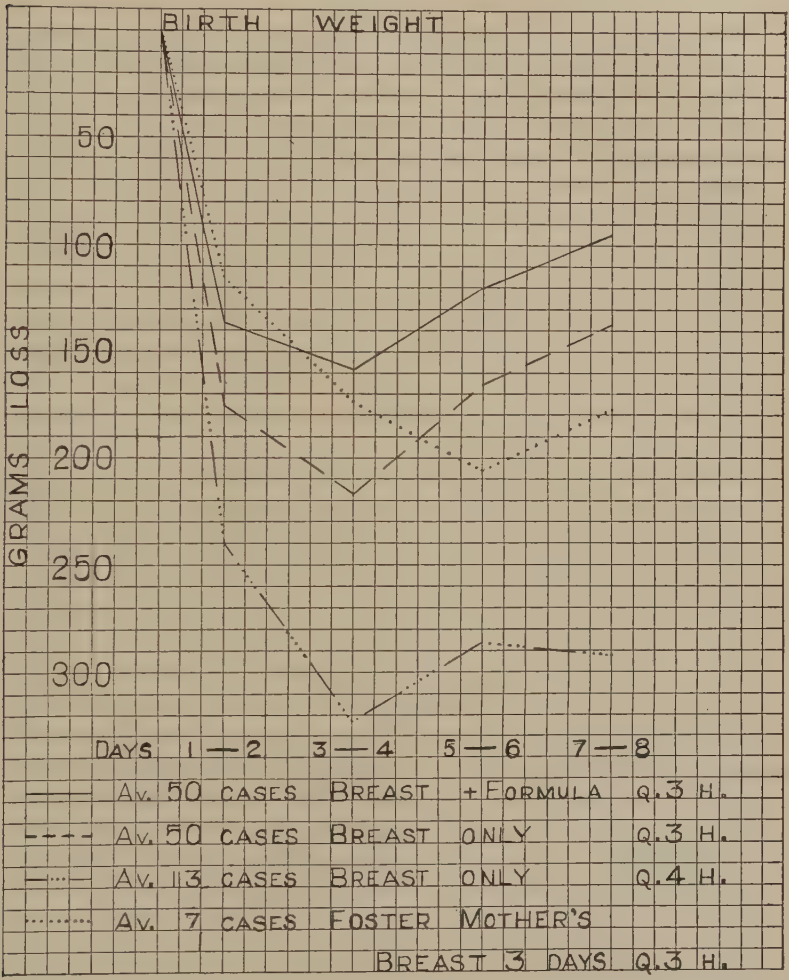

FIG. 212.—Chart showing loss from birth-weight of infants fed in different ways. (Bailey and Murlin, Amer. Jour. of Obstetrics, 1915, lxxi, No. 3, Fig. 1.)

blood. Roth[152] also made determinations of the same factors by the refractometer method and established a parallelism between water concentration and the weight curve, while von Reus[166] applying these facts to actual practice, gave a very liberal amount of water from the second day on and in some cases obtained a return to birth weight as early as the seventh day. Ramsey and Alley[144] state that the administration of water to infants who received an average amount of breast milk did not effect the weight curve, but with infants receiving little or no breast milk the initial loss in weight was less when water was given. A part of the water loss, however, is apparently permanent and can not be replaced. The reason for this will be readily understood when we remember that the child has passed from an aqueous medium to an atmospheric medium. Immediately after birth the skin is turgid with water absorbed from the amniotic fluid; 24 hours later it begins to assume a normal appearance. The loss in weight correspondingly is most rapid the first and second days (see chart, Fig. 212).

Different authors give different amounts as the normal or physiological loss of weight. Pies[140] gives the average loss for 108 infants of primiparæ at 300 gm. the first week or a total of 9 per cent. of the birth weight. The average loss for 42 infants of multiparæ was 270 gm. or 8 per cent. of the original weights. All of these infants had been fed five times in 24 hours after the first day. Sadoffsky[167] by feeding the newborn infants 12 times in the first day and at two-hour intervals in day time and four-hour intervals at night was able to keep down the initial weight loss to 188 gm. on the average or 5.7 per cent. of the original weight. Benestad[27] has reviewed the entire literature bearing on the initial loss of weight and has cited various attempts made by Altherr, Kruger, Ingerslav, and others to prevent it by placing the newborn to the breast of mothers whose own babies had been born several days previously. Strangely enough, in most of the cases studied the loss of weight instead of being corrected was aggravated. Benestad gives his own experience to the same effect and concludes that the cause is found in the inability of the alimentary organs to perform their proper functions immediately. Exceptions to the rule, according to this author, are those children who are most robust at birth. Schick,[171] however, by means of complementary feedings of breast milk from foster mothers was able in nine cases to prevent the initial loss in weight altogether. The extra feedings were begun from three to six hours after birth and were repeated every two or three hours. An amount varying from 8 to 15 per cent. of the body weight was given irrespective of the amount received from their own mothers. None of the infants suffered any inconvenience and two actually gained in weight.

Several years ago, convinced that infants who suffered the greatest loss during the first week were those who subsequently did poorly, especially on artificial feedings, Bailey[7] instituted at Bellevue Hospital a plan of giving formula feedings from the very first day. The breast milk was not discontinued, but after ten minutes of nursing each time the child was permitted to have from a bottle all he would take of the formula. In only one case out of a large number fed in this way did any adverse symptom arise, and in this single case administration of an enema relieved the condition.

The chart (Fig. 212) shows the comparison of the average loss in weight of 50 infants fed on the breast every three hours during the day and every four hours at night with 50 fed in the same way, but, in addition, as much as they would take of the formula at the same intervals as stated above. The cases were taken consecutively, eliminating all babies weighing at birth under six pounds and those whose mothers were known to be abnormal. The pure breast-fed infants for comparison were taken from the months in October and December, 1913, while the breast-and-formula-fed were born in October and November, 1914. For comparison with these curves are two others representing averages for a smaller number of infants, one showing the effect of four-hour intervals and other feedings by foster mothers. The four-hour interval was soon discontinued because of greater initial loss. The average weights in all cases were taken from lowest weights recorded at two-day intervals. This method of averaging was adopted because weights were not taken on Sundays and as a result some eight-day charts lacked two weighings; also many of the first-day weighings were made only a few hours after birth. The curves could not be carried farther because so many of the infants went to their homes on the ninth day. The group which showed the smallest loss were those given both breast and formula feedings. After these, perhaps, is the smaller group which were put to the breast of foster mothers every three hours. The average maximum loss for the fifty who showed the best results was only 150 gm. and there was a more prompt return toward normal. For the foster-fed the loss in weight was more gradual but just as great in the long run as for those nursed only by their own mothers. The foster-feeding, however, it should be noted, was kept up only for three days.

Since, as was first shown by Margaret B. Wilson[208] in Lusk's laboratory, and later confirmed by Rost[151] and by Rubner[161] and unconsciously by many other students[61] of growth in animals, there is a definite relationship between caloric intake and rate of growth—it would be most interesting to investigate the influence of easily assimilable carbohydrate supplements upon the rate of the initial loss and recovery therefrom.

The formula used by Bailey was intended to approximate the composition of two- or three-day colostrum, as given by Camerer and Soldner.[37] Later, however, it was found by analyses performed by Dr. F. C. Gephart in connection with the same investigation that the composition of colostrum taken in the maternity wards of Bellevue Hospital was quite different from this.

Composition and Heat Value of Colostrum.—These analyses as well as those of other American authors who have published recently are summarized in the table below.

TABLE 22.—RECENT ANALYSES OF EARLY HUMAN MILK (COLOSTRUM)

Date	Author	Number of analyses	Days of lactation	Average composition			
				Protein, per cent.	Fat, per cent.	Lactose, per cent.	Calories per 100 c.c.
1915	Gephart	5	2 and 3	2.3	2.9	7.1	65.3
1915	Holt, Courtney and Fales	5	1 to 12	2.25	2.83	7.59	64.6
1917	Hammett	...	3 to 11	2.00	3.62	6.08	74.3

Holt, Courtney and Fales,[78] extending the division of lactation, suggested by Schloss,[172] call attention to the high ash, as well as the high protein of the colostrum, compared with later milk. Their analyses of the ash constituents deserve a separate table.

TABLE 23.—AVERAGE COMPOSITION OF ASH IN DIFFERENT PERIODS OF HUMAN LACTATION (HOLT, COURTNEY AND FALES)

Period	Number of analyses	Total ash	CaO	MgO	P_2O_5	Na_2O	K_2O	Cl
Colostrum (1 to 12 days)	5	0.38	0.045	0.010	0.041	0.045	0.094	0.057
Transition (12 to 30 days)	6	0.241	0.041	0.006	0.040	0.026	0.071	0.058
Early mature (1 to 4 months)	9	0.206	0.049	0.008	0.034	0.015	0.054	0.035
Middle mature (4 to 9 months)	8	0.207	0.046	0.007	0.034	0.013	0.061	0.036
Late milk (10 to 20 months)	10	0.198	0.039	0.007	0.030	0.019	0.058	0.044

Hammett[68] gathered milk on five alternate days, beginning with the third of lactation, from eight different healthy subjects. He noted especially the relative uniformity between different subjects, of the protein content as contrasted with the other two organic constituents; but found a tendency toward a reciprocal relation on different days for the same subject, between lactose on the one hand and protein and fat on the other. Denis and Talbot[46] made some interesting observations on the differences in composition between different stages of lactation, before and after nursing, between the two breasts and at different hours of the day; but they include only five analyses for the colostrum period, three of which were from a patient ill with pneumonia. In common with Hammett they were impressed with the gradual rise in lactose secretion, *pari passu* with the decline in protein from colostrum in transition period and beyond.

The average of the three sets of analyses of colostrum expressed from the breast gives a physiological, *i.e.*, utilizable, heat value of 653 to 743 calories per liter. This value comes within the range given by Langstein, Roth and Edelstein[95] for a certain group of cases who, according to these authors, yield a thin, white and watery secretion as opposed to another group which produce a thick, yellow and viscous fluid the first few days. For the former they found a heat value of 600 to 800 calories; for the latter 1,200 to 1,500 calories, per liter. Rubner and Heubner[162] give, for the fully established breast milk, values very similar to those found by the American authors for the colostrum, but the estimations of O. and W. Heubner[76] for full breast milk are 800 to 888 calories per liter. It is evident from these comparisons and from those brought together by Czerny and Keller[42] that human milk varies much in composition at all periods of secretion, and it is not unlikely the character of the milk produced is subject to hereditary transmission, as it is in cows. However this may be, and whichever value may prevail in any given case, we may be assured that colostrum is not lacking in energy. It is probably always as high, and oftener higher than the mature secretion, of the same breast. It is the ideal food for the newborn, but the trouble is there is so little of it. Von Reuss[146] gives a table containing the results of 15 authors on the estimation of the amount of breast secretion made in all cases by determining the daily amount gained during nursings. The amount given by the three authors having the largest number of cases to average are tabulated below together with the recent results of Ramsey and Alley[144] determined by five nursings in 24 hours at four-hour intervals. Where the colostrum is thin and watery having a heat value of, say, 650 calories per liter, it is evident that even if the average amount were secreted it is not until the fifth day that an energy supply of 200 calories for the 24 hours could be counted upon. If it is of the thick variety, an average production in grams would yield 300 calories on the third or fourth day. Quite probably, however, there is a relationship between the amount produced and the character of the secretion which the von Reuss table does not exhibit. There is no assurance, certainly, that the breast furnishes anything approaching the full energy requirement of an infant of average weight before the fourth or fifth day. Assuming a very common weight of 3.5 kg. (less than eight pounds), the requirement may be summarized as follows:

TABLE 24

Name	Number of cases	Days							
		1	2	3	4	5	6	7	8
		Grams per diem							
Jaschke, 1909	18	19	90	193	260	339	403	415	470
Opitz, 1911	75	56	197	296	371	431	462	455	485
v. Reuss, 1914	25	..	54	173	263	327	254	362	390
Ramsey and Alley, 1918	300	..	39	100	170	234	275	304	336

Basal metabolism, at 45 calories per kg.	157.5 calories
Activity metabolism, at 30 per cent. increase	47.3 calories
Growth metabolism, at 25 per cent. of basal	39.4 calories
Non-absorption at 10 per cent. of total	24.4 calories
Total	268.6 calories

Even omitting the requirement for growth, at least 350 c.c. of secretion with a heat value of 650 calories per liter would be required to prevent loss of combustible material from the body.

This review of the energy requirement of the newborn reaches the same conclusion as that emphasized by Morse and Talbot[119] and by Ramsey and Alley; namely, that the energy quotient of 100 calories per kilogram as given by Heubner and other observers is unnecessarily high. Ramsey and Alley observed satisfactory gains in weight on a quotient of 43 to 74 calories per kilogram.

Energy Metabolism from Two Weeks to One Year of Age.—The energy metabolism of infants over two weeks of age has been much more extensively studied. Beginning with the fragmentary observations of Forster in 1877, which have already been cited (p. 584) down to and including 1920, not less than a score of important researches have been published on the normal child. These fall into two groups according to the method of observation adopted. Table 25 presents a complete list of the observations made on the resting child whether waking or asleep and at various times with reference to the ingestion of food. A considerable degree of concordance can be traced in the results, notwithstanding the diversity of methods employed; but there are important differences which will engage our attention as we proceed.

The earlier researches by the indirect method were made for the most part upon a few individuals, but these were studied very exhaustively with a view to account for all of the food ingested. The later researches by the indirect method and all the observations upon normal infants by the direct method have sought rather to establish standards of metabolism with which abnormal or pathological cases could be compared. Consequently a considerable number of subjects have usually been employed. Several of the investigators have selected from their own cases those whom they consider normal. In the case of some others it has been necessary to select from the published tables those whom the authors describe as of normal weight for age.

Methods.—The primary reason for separating the infants beyond 14 days of age from the newborns is a practical one. Up to the age of two weeks the newborn child in the hospital is under the care of the obstetrician. Quite commonly in the home also after normal delivery and the child is well started at the breast the pediatrist is called in only when the child presents some nutritional emergency. The nutritional story is continuous, but the two chapters are of interest to two different groups of readers and for this reason have been separated.

Also the methods of study in the maternity ward are of necessity somewhat different from those employed in the children's ward. The presence of the mother and the desire to establish breast feeding dictate the nutritional policy in the former, while in the latter the search for a suitable formula is the uppermost thought. Again while normal babies are the rule in maternity wards they are the exception in children's wards. Certain procedures are therefore quite justifiable in the one group, which would not be warranted in the average case in the other.

Collection of Urine and Feces.—One of these is the use of a so-called metabolism frame for collection of the urine and feces. Where the feces must be examined to judge of the success or failure of a formula and where additional information for the welfare of the child can so often be supplemented by examination of the urine, one does not hesitate to employ the frame, and this facilitates the collection of data regarding the energy metabolism. Rubner and Heubner, Niemann, Howland, and Murlin and Hoobler in their energy studies have made use of the frame and have included the factors necessary for calculation of the protein metabolism (p. 535 and later section). While it is possible in many instances—especially in comparisons of infants on identically the same diet—to secure fairly accurate results without knowledge of the nitrogen in the urine, this procedure is certainly not justified when different diets are employed, either with the same child in different periods or with different children. The method of calculation

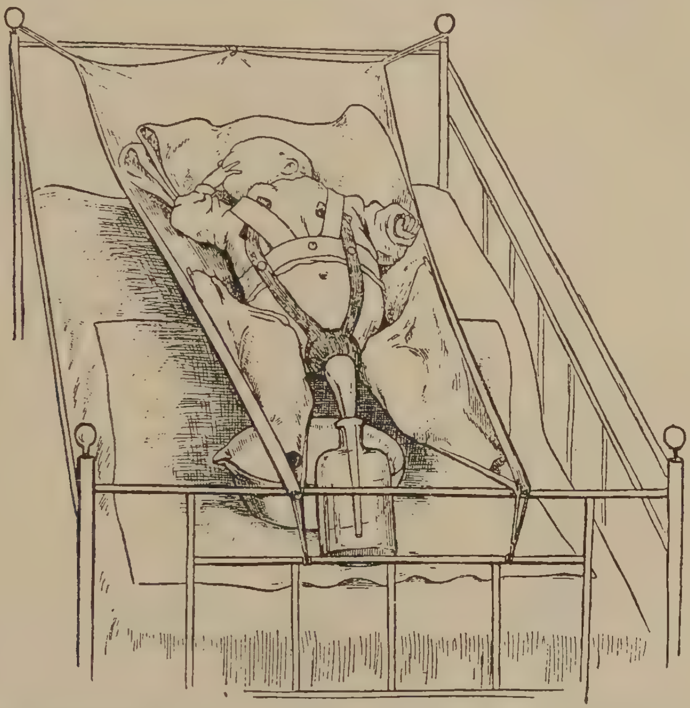
FIG. 213.—Metabolism frame. (Bendix, Tigerstedt: Handbuch der physiologischen Methodik., Leipsic, 1911, I Bd. 3d Abth., Fig. 29, p. 38.)

TABLE 25.—METABOLISM OF NORMAL INFANTS OVER TWO WEEKS OF AGE

Indirect Method												
Authors	Date	Type of apparatus	Subjects					Metabolism				
			No. or name of infants	Age, months	Weight, gm.	Condition	Food	Per kgm. and hour		Per sq. m. and hour, CO_2 (Meeh) $11.9\sqrt[3]{(w)^2}$	Cal. per kgm. and hour	Cal. pe sq. m and 24 hr. (Meeh)
								CO_2, gm.	H_2O			
Normal Infants												
Forster..........	1877	Pettenkoffer-Voit, short periods	2	14 da. 60 da.	....	....	....	1.0 1.2	1			
Rubner and Heubner.	1898	P-V, 6 days	Child J	2¼	5235	Healthy; quiet	608 gm. mother's milk	0.96	1.59	13.5	....	1006
	1899	P-V, 7 days	Child M	7½	7636	Healthy; quiet	994 c.c. whole milk + 3 per cent. sugar	1.05	1.85	17.3	....	1143
	1904	P-V, 3 days	Child C	5½	9600	Healthy; restless	1258 gm. mother's milk	1.01	2.03	17.4	....	1219
Schlossman and Murschauser.	1909	R-R, hourly periods	Child S	4½	5790	Sleeping	Fasting 18 hr. after food	0.91	....	13.78		
			Child L	3	5000	Sleeping; absolutely quiet	Fasting 18 hr. after food	0.86	....	12.33		
			Child N	6	5400	Sleeping, absolutely quiet	Fasting 18 hr. after food	0.86	....	12.91		
			Child N	7	5575	Restless	Fasting 18 hr. after food	1.00	....	17.85		
	1910	R-R, hourly periods	Child Sim	6	5010	Sleeping almost perfectly quiet	Fasting 18 hr. after food	0.85	....	12.27		
			Average of 3 female infants, 87 to 180 days.			Sleeping almost perfectly quiet	....	....	....	12.22	....	859

Howland.........	1911	Atwater-Rosa-Benedict, respiration calorimeter	Child 1 21 Mar.	3	4650	Sleeping	1200 c.c. ½ milk + 5 per cent. milk sugar	1.10	....	15.28	....	1026
			Child 2 Feb. 23	7	4320	Sleeping	⅔ milk + 5 per cent. milk sugar + 30 gm. malt ext.	1.28	....	17.43	....	1249
Niemann.........	1913	P-V, I period, mean of 6 days	Child Th.	4	5117	Quiet, except 1st day	Buttermilk and sugar	1.31	....	19.00	....	1347
		IV period, 12–17 days	Same	9½	6000	Very quiet	Whole milk	1.20	1.47	18.3	....	1443
Benedict and Talbot.	1914	R-R, short periods	Average of 6 infants	3–10	Normal weight	Sleeping or very quiet	Variable	....	....	11 93	2.33	880
Same......	1914	Same	Average of 3 infants	All 7 mo.	"All moderately under weight."	Sleeping or very quiet	Variable	....	....	13.2	2.49	926
Murlin and Hoobler.	1915	R-R, hourly periods	Average of 4 infants	2–3	2 normal weight 1 over weight 1 under weight	Sleeping only	Fed just before experiment	0.89	....	.....	2.17	843
			Average of 2	10½–12	1 normal 1 slightly over normal	Sleeping	Fed just before experiment	....	....	.....	2.58	1104
Hellesen[71–a]......	1915	P-V, 2–3 day experiments, 9 days apart	Average of 1 infant	....	6684	....	....	....	....	.....	2.83	1434
											3.01	1560

TABLE 25.—METABOLISM OF NORMAL INFANTS OVER TWO WEEKS OF AGE.—*Continued*

Direct Method

Authors	Date	Type of apparatus	Subject					Metabolism, cal. per kgm. and hour
			No. or name of infants	Age, months	Weight, gm.	Condition	Food	
Richet	1885	Richet calorimeter à siphon	18 observations	Not given	Normal	Quiet	Not given	4.0
Langlois	1887	Richet calorimeter à siphon	17 observations	Not given	Av. 7.00	Quiet	Not given	3.4–6.0
Bonniot	1900	D'Arsonval anemo-calorimeter	Exact number not given	15 days to 8 months	8–17	Quiet	Not given	2.0–2.8
Saint-Albin	1904	Richet calorimeter	5 normals	....	8–11	Quiet	Not given	3.2–4.0
Variot and Lavialle	1912	D'Arsonval anemo-calorimeter modified by Lavialle	6 normals	18 days to 12 months	1.3–9.0	....	....	3.0–3.5

of the total heat production employed by Rubner and Heubner and followed by Niemann in their several studies is somewhat different from the method of Zuntz and Schumberg which has already been explained (p. 535) but involves also the use of the nitrogen in the urine.

Bendix was the first to employ a metabolism frame. This has been modified and inproved by Finkelstein and by Langstein. A number of others have been designed and have been used in this country. The one designed by Hoobler[82] has been used by him and by the writer in the research on hospital children at Bellevue Hospital already referred to. It proved in every way a most convenient arrangement. The frame was made somewhat smaller than the dimensions given by Hoobler in his original article in order to be admitted to the respiration chamber. The arrangement devised by Courtney and Fales[41] is probably just as good, especially for very young infants. It is necessary for the greatest accuracy to use the frame for the entire 24 hours, although by taking sufficient pains certain children, if old enough, may be induced to pass the urine at nearly regular intervals. Only in exceptional cases would the use of the catheter be justified, even though careful irrigation with warm boric acid would in all probability eliminate the chances of infecting the bladder. A soft rubber catheter kept in an aseptic solution or recently boiled may be used with female children. Table 26 selected from Table 4 of Murlin and Hoobler's[126] paper gives amongst other data the 24-hour excretion of nitrogen and shows how regular this may be (Child 4 and 6)when the intake of food

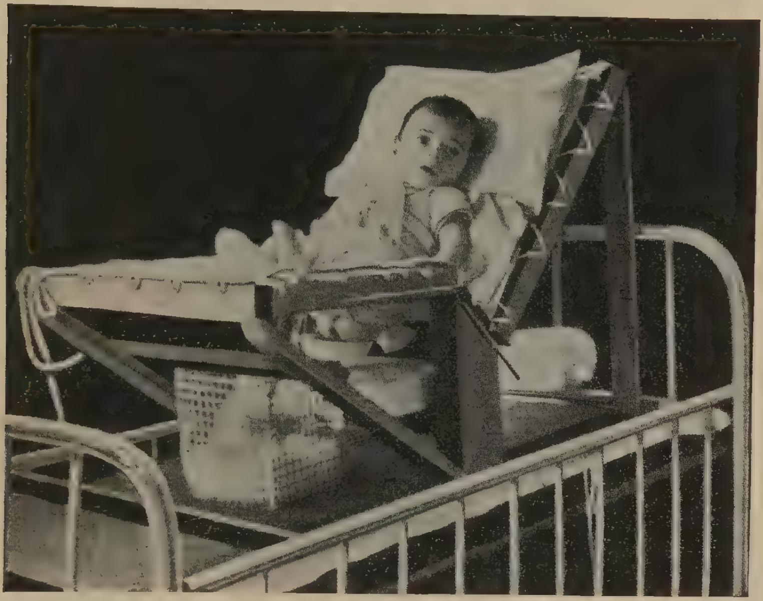

FIG. 214.—Metabolism frame of Hoobler. (Amer. Journ. Dis. of Children, 1912, iii, Fig. 4, p. 255.)

is constant from day to day and how it may vary (Child 3) when the formula is changed.

Control of Conditions.—It can not be too strongly emphasized that definite knowledge of metabolism can only make progress as definite ascertainment of all the conditions under which the observations were made and of those conditions preceding the observation which may be supposed to influence the assimilation and oxidation of the food is rendered possible. Time is often saved by taking note of the behavior of the child for some days before placing him in the respiration chamber. Schlossmann and Murschauser[178] refer to the facility which one acquires with experience in picking out suitable subjects. The metabolism frame is a good criterion. A child which will endure the restraints of a frame for several days without undue annoyance will usually behave well in the respiration chamber. The first day on the frame, however, is not a fair test. On the other hand, a child which does not find itself comfortable on the frame by the third day should not be employed.

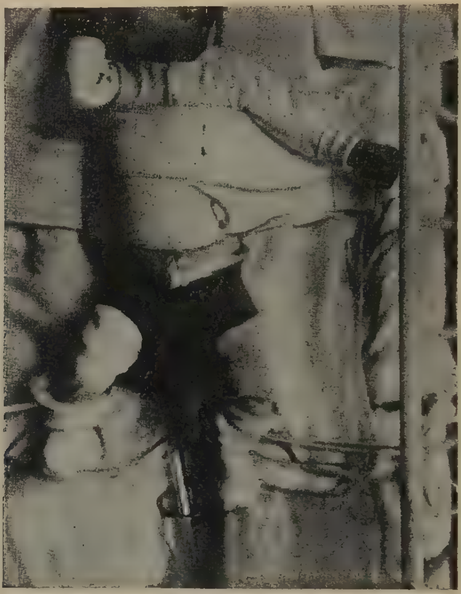

Fig. 215.—Metabolism bed of Courtney and Fales. (Amer. Journ. Dis. of Children, 1915, x, 412, Fig. 4.)

It goes almost without saying that unless the effect of change in diet is the point under investigation, the diet should be uniform both in quality and quantity and should have been thoroughly established before observations on the energy metabolism begin. The respiratory quotient will be influenced especially by the proportion and even by the kind of carbohydrate incorporated in the formula. After breast feed-

TABLE 26.—SLEEPING METABOLISM OF FOUR INFANTS (MURLIN AND HOOBLER)

Date	Name and age	Condition	Weight	Food distribution of calories in per cent. of total	Last feedings			Respiration period	CO₂ elim. l.	O₂ abs. l.	R. Q.	N in 24-hr. urine	Cal. per hour	Temp. of resp. incubator	
					Amt., ounce	Time	Total calories							B.	E.
1914														°C	°C
2/13	Child 2, A. Sa., 2 months	Normal boy overweight	5890	At breast	?	10:30	?	12:52– 1:32	1.545	1.811	0.85	......	13.92	29.7	30.3
2/14	....	....	5810	Form P10; F22.5; C H67.5	3	9:00	42	12:22– 1:13	1.871	2.070	0.90	0.658	12.00	30.3	30.2
				Mother's milk	2	11:00	25	1:13– 2:04	2.406	2.700	0.89	......	15.42	30.2	30.4
2/16	....	....	5692	Mother's milk	3	9:00	38	10:29–11:31	2.164	2.509	0.86	0.812	11.78	28.4	28.6
								11:31–12:38	4.050	3.859	1.04	......	17.45	28.6	28.5
2/17	....	....	5690	Formula	3	10:30	37	11:27–12:27	2.301	3.051	0.75	......	14.50	27.4	27.5
				P12; F20; CH67	3	10:45	37	12:27– 1:27	2.581	2.914	0.88	......	14.20	27.5	28.3
2/27	Child 3, C. P., 3 months	Atrophic	2462	Formula	3	9:00	38	11:48–12:48	1.570	1.448	1.08	......	7.35	28.1	28.4
				P11; F25; CH64	3	10:45	38	12:48– 1:48	1.430	1.429	1.00	......	7.15	28.4	28.7
3/ 3	....	....	2515	P11; F25; CH64	3	9:00	38	10:40–11:40	1.569	1.448	1.08	0.602	7.35	27.7	27.8
					½	10:30	7	11:40–12:40	1.369	1.499	0.91	......	7.43	27.8	28.2
						p.m.									
3/ 7	....	....	2444	Formula	3	1:00	38.4	3:03– 4:03	1.114	1.150	0.97	1.036	5.65	28.3	28.6
				P11; F75; CH14	3	2:30	38.4	4:03– 5:05	1.140	1.324	0.86	......	6.37	28.6	28.9
						a.m.									
3/10	....	....	2434	Formula	3	9:30	35.4	10:32–11:32	1.364	1.675	0.81	1.230	7.97	29.1	29.2
				P29.6; F55.7; CH14.7				11:32–12:32	1.282	1.778	0.72	......	8.27	29.2	28.9
3/17	Child 4. E. N., 3 months	Underweight	4115	Formula	3	9:00	42	11:10–12:10	2.154	2.188	0.98	1.120	10.87	28.6	29.0
				P10; F24; CH66	3	10:30	42	12:10– 1:10	1.968	2.208	0.89	......	10.75	29.0	28.9
3/18	....	....	4134	Formula	3	9:00	42	11:10–12:00	2.295	2.072	1.11	1.092	10.53	28.5	29.1
				P10; F24; CH66	3	10.30	42	12:10– 1:11	2.503	2.432	1.03	......	12.04	29.1	29.7
3/19	....	....	4147	P10; F24; CH66	3	9:00	42	11:10–12:10	2.099	2.096	1.00	1.064	10.47	28.8	28.9
					3	10:30	42								
3/24	Child 6, W. L., 2 months	Normal	4364	Formula	3	9:00	39	10:45–11:45	1.995	2.152	0.92	0.924	10.56	29.1	29.2
				P11; F25; CH64	3	10:10	39	11:45–12:45	2.416	2.673	0.90	......	13.09	29.2	28.8
3/25	....	....	4371	Formula	3	9:00	36	10:38–11:38	2.015	2.190	0.92	1.008	10.74	28.8	29.1
				P12; F27; CH61	3	10:15	36	11:38–12:38	2.036	2.266	0.87	......	11.09	29.1	29.2
3/26	....	....	4350	P12; F27; CH61	3	9:00	36	11:10–12:10	2.040	2.181	0.93	1.008	10.75	29.2	29.4
					3	10:50	36	12:10– 1:10	2.095	2.309	0.92	......	11.31	29.4	29.5

ing also the quotient will always be higher the first hour or hour and a half than at any subsequent time. These facts are well brought out in Table 26. (For a further discussion of these points see pages 582 and 638.)

Records of Movements, Pulse, Respiration, etc.—It is by this time so well understood that muscular activity increases the energy metabolism, that no further stress need be laid upon the necessity of knowing the state of muscular activity of the subject, whatever the object of the observations may be. Schlossmann[176] and F. G. Benedict[20] deserve the credit of having brought this matter to full realization by most investigators.

As indicated on page 608 the most satisfactory form of record of muscular activity would be one which would translate the motions of the subject into some unit of measurement capable of expression as mechanical work. Otherwise a graphic record may vary considerably with the sensitiveness of the recording mechanism, which in turn is subject to variation from a number of causes. Moreover a record of any kind should not be relied upon solely. Notes are always necessary by way of elucidation.

Several recording devices have already been described for observations upon the newborn. Only one of these, the tambour-bed, is scarcely practicable with older children. With the child on a metabolism frame the following method employed by Murlin and Hoobler, will be found very satisfactory. The writer does not believe it is necessary to record the pulse except as an additional and somewhat gratuitous source of information, regarding muscular activity; for to the evidence already adduced by Murlin and Hoobler that the pulse rate is not proportional to the metabolism in infants, Harris and Benedict have now furnished data which prove that next to no correlation between pulse rate and basal metabolism exists in newborn babies (p. 608). Morever, from the paper of Benedict and Cathcart on muscular work, it is evident that pulse rate is no criterion of energy release in the skeletal muscles. The method by which Murlin and Hoobler demonstrated this lack of correlation in infants from two months to one year of age is shown in the accompanying illustrations and may be found useful for pathological cases. An alternative method which was used with the newborn and which may be used with older infants, especially when it is necessary to darken the respiration chamber to induce sleep, is to attach the receiver of a Bowles stethoscope by means of adhesive tape, directly to the upper left side of the chest, and connect this with the auriculars outside the chamber by means of a long rubber tube. The pulse can be counted very satisfactorily as a rule and, if a nurse can be spared to listen continuously, the least whimper of the child can be noted.

The graphic method for pulse consists in having a small cuff such as is used in making blood pressure readings in the infant[81] placed about one thigh. From this a rigid-walled tube is led to a glass connection passing through the wall of the apparatus, thence to a T-tube (Fig. 217) just in front of the pressure bottle) one limb of which passes to a small air pump and the other to a second T-tube (to the left of the pressure bottle in Fig. 217). To the second T a mercury manometer is attached by one limb and a pressure bottle by the other, and from the pressure bottle, finally, a transmission tube leads to a recording tambour covered with very light rubber. A pressure of from 30 to 40 mm. of mercury is sufficient to give a legible motion to the lever and this pressure does not interfere with the circulation or with the repose of the infant. In the experiments referred to, it was found that two very thin finger cots placed one inside the other sufficed to reduce the pressure in the pressure bottle to a point which could be borne by the tambour and at the same time to transmit a sufficient wave to the tambour for a legible record on smoked paper. A long-paper kymograph was so arranged and timed that one complete revolution coincided with an hour's observations.

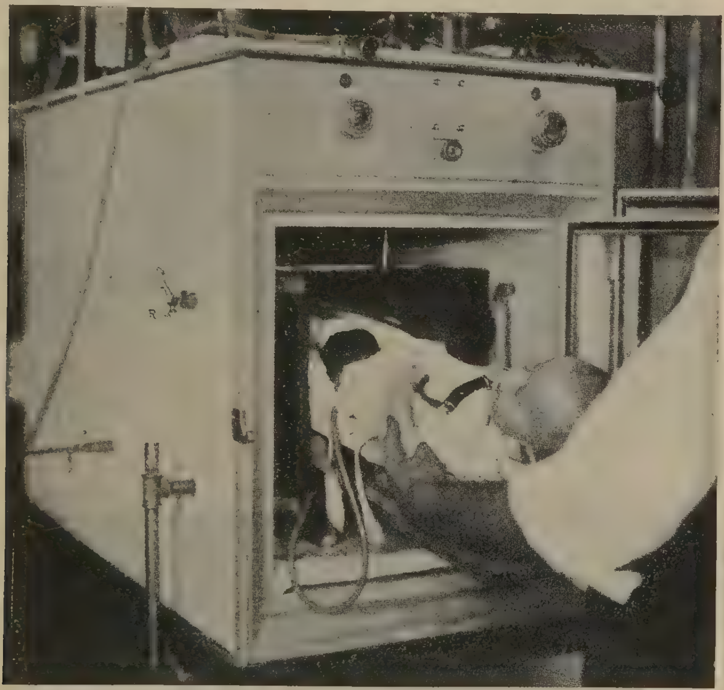

FIG. 216.—Showing arrangement of small cuff on the leg of infant for recording pulse, and small pneumograph around chest for recording respirations. The rubber tubing connecting with the tambours on top of the incubator are seen penetrating the outside wall. P, tubing for pulse; R, tubing for respiration. (Murlin and Hoobler, Amer. Journ. Dis. of Children, 1915, ix, Fig. 1, p. 89.)

Respiration.—For recording the respirations and incidentally the movements of the body, a short pneumograph (Fig. 218) may be used, but for the infant sufficient distensibility can be secured only by replacing the rubber tubing with which these instruments are commonly provided with a much thinner one. The finger of a surgeon's rubber glove has been found appropriate.

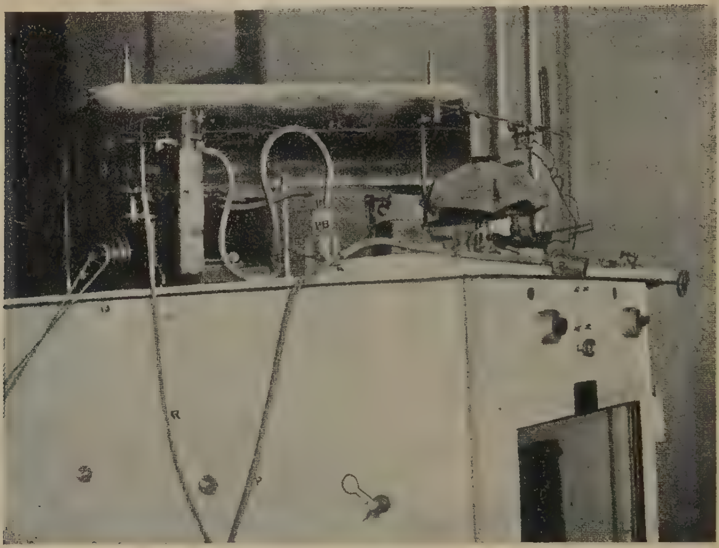

FIG. 217.—Showing arrangement of recording devices on top of the incubator. The tube P connects a T tube (1) with the hand pump and (2) with another T, which in turn connects with the mercury manometer M, and the pressure-reducing bottle PB. From the pressure-reducing bottle a final tube leads to the recording tambour. (Murlin and Hoobler, Amer. Journ. Dis. of Children, 1915, ix, Fig. 2, p. 89.)

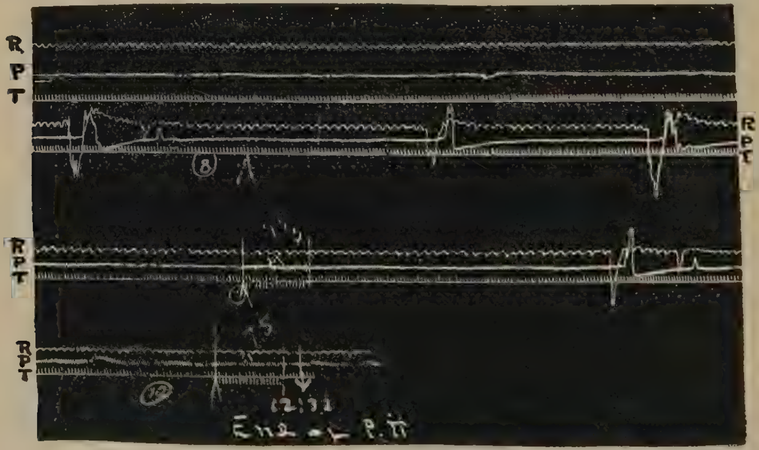

FIG. 218.—Sample record of respiration, R, pulse, P, and time in seconds, T. The record shows several readjustment movements on respiration and pulse records; also method of counting pulse under reading glass by drawing parallel lines 20 seconds apart. (Murlin and Hoobler, Amer. Journ. Dis. of Children, 1915, ix, Fig. 3, p. 90.)

For conveniences in counting the respirations (or pulse) a time record should be obtained simultaneously. Figure 218 exhibits a typical record of pulse, respirations, and time, and the method of counting under a reading glass.

It is a perfectly familiar fact that a child, even when perfectly healthy, will not lie absolutely still for a long time even in profound sleep. Sooner or later a sensory irritation from some part of the body will cause a short series of movements by which the irritation is removed. If the irritation arises merely from pressure, the movements are usually very brief and have been designated "readjustment movements" to distinguish them from more extensive or more complex movements incident to waking or caused by pain. Figure 218 shows what is meant by this term. They occur in the record of every sleeping infant, but in the experiments at Bellevue Hospital were seen most frequently in an underweight child on the third day of a protein-milk formula. Doubtless they are aggravated, like the itch for muscular exercise, or fidgetyness, by a heavy protein diet.

Comparable Conditions.—The most approved procedure for securing comparable conditions in different children is to place them in the respiration chamber immediately after feeding. If the precaution has been taken to keep the subject awake for some hours previously, one can then be certain of two or three hours of quiet sleep. By employing the same formula with different children of the same age and apportioning the organic constituents according to age in children of different ages, comparable conditions as regards the dynamic effect of foods are secured. Schlossmann and Murschauser and later Howland studied the energy metabolism of infants while fasting. *i.e.*, about 18 hours after last feeding; but their results are not as concordant (Table 25) as those of more recent observers following the procedure just outlined. It is natural for a child to cry when hungry, and not to be quiet otherwise except when asleep. If sleep occurs without feeding, it is most probably the sleep of exhaustion or of stupor due to illness. The fact that an even lower metabolism may be obtained in normal sleep after feeding than in fasting (Table 25) denotes either that the sleep of fasting is not quiet and undisturbed, or that the ordinary food has no dynamic action (see section on "Dynamic Action," p. 634).

Environing Temperature.—While the effect of external temperature aside from its influence in causing muscular motions is still in dispute, there is no doubt regarding the necessity of having comparable conditions in different experiments. With infants, if the external temperature falls so that a sensation of chill is produced, the natural result is for the infant to cry, for this is the only means it has of increasing the metabolism. This question is closely bound up with that of clothing. If a lower temperature is chosen at which the respiration chamber is to be maintained, the amount of clothing necessary to prevent crying will be greater than if a higher temperature is chosen. In the writer's experience a temperature of 28°C. is most conducive to quiet sleep with no other clothing than a knit upper garment and a pair of stockings.

This sort of clothing is well adapted also to the metabolism frame. Under these circumstances the average child will not perspire sensibly unless he cries very hard.

Body Temperature.—So long as normal infants are being studied the only object in recording the body temperature is to confirm other evidence that the subject really is normal at the time of observation. There is no evidence that slight variations of temperature influence metabolism perceptibly (p. 608).

Comparison of Direct and Indirect Methods.—While for the sake of completeness the observations of many students of metabolism have been grouped together in the same table (p. 620), it must not be inferred that the several methods employed are regarded as strictly comparable. For example: The direct methods employed by the French observers are not strictly comparable with that of the Atwater-Rosa-Benedict calorimeter with which Howland's experiments were made. The French take no account of the heat of vaporization nor of that stored in or lost from the body itself. Further the Richet *calorimeter à siphon* is not strictly comparable with the D'Arsonval *anemo-calorimeter*. Bonniot[34] criticises the former because the interior temperature is not regulated, the clothing of the infant is not adapted to the environment,

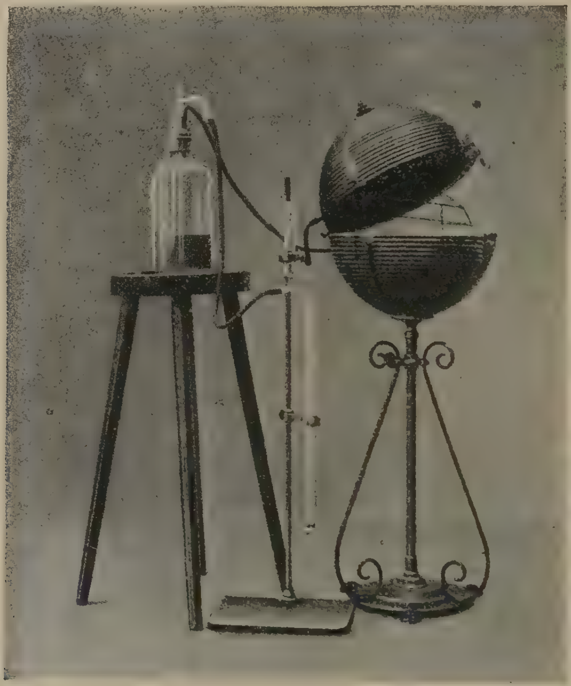

FIG. 219.—Calorimeter à siphon. (Richet) Tigerstedt: Handbuch der physiologischen Methodik, Leipsic, 1911, I Bd. 3d Abth., Fig. 17, p. 196.

and there is no ventilation, the child (Fig. 219) being shut up in the egg-shaped chamber only for a period long enough for the conditions to become stable. It would appear, however, from Bonniot's remarks that this would require at least one hour, and he draws attention to older experiments by D'Arsonval which seem to prove that poor ventilation itself increases heat production.

The principle of this apparatus consists in determining the expansion of the air contained between the two walls by means of a manometer, a rise in pressure, however, being avoided by balancing against the manometer a column of liquid in a siphon (Fig. 219).

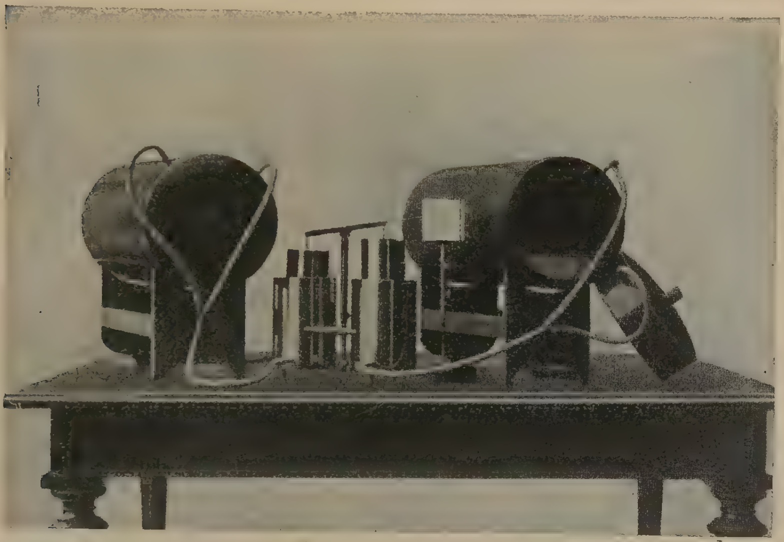

FIG. 220.—Calorimeter thermo-electrique of D'Arsonval. (Tigerstedt: Handbuch der physiologischen Methodik, Leipsic, 1911, I Bd. 3d Abth., Fig. 18, p. 197.)

The calorimeter which was prepared by D'Arsonval for Bonniot's studies is thus described by the inventor.[44] It consists of a rectangular box, measuring 1 meter × 1.7 meter × 80 cm., having near its center a shelf upon which the child is placed. The chamber is covered with a glass top upon which is fixed a chimney 50 cm. high × 6 cm. in diameter. Air enters below the shelf, passing first below the infant then above him before being drawn out at the chimney. An anemometer placed at the top of the chimney may be used to record the volume of air passing through after being warmed by the infant's body. The rise in temperature is recorded by a differential thermometer one bulb of which is in the chimney and the other in the outer air. The instrument is calibrated by means of incandescent lamps of known capacity placed upon the shelf inside and enveloped in a covering similar to that which covers the baby in an actual experiment and made up so as to occupy about the same volume.

The apparatus used by Variot and Lavialle[196] is constructed upon the principle of another D'Arsonval instrument, but modified by Lavialle. The original D'Arsonval form, known as the thermo-electric calorimeter, consists of two closed metallic cylinders of the same size, in one of which the infant is placed, and in the other an electrical heating unit of known capacity. The air enclosed within the double wall of each cylinder is connected to one limb of a differential manometer. Naturally the one which receives the greater amount of heat tends to expand the more and records the greater amount of pressure. By calibration with lamps of known capacity the readings of the manometer can be established in terms of calories. (Fig. 220.)

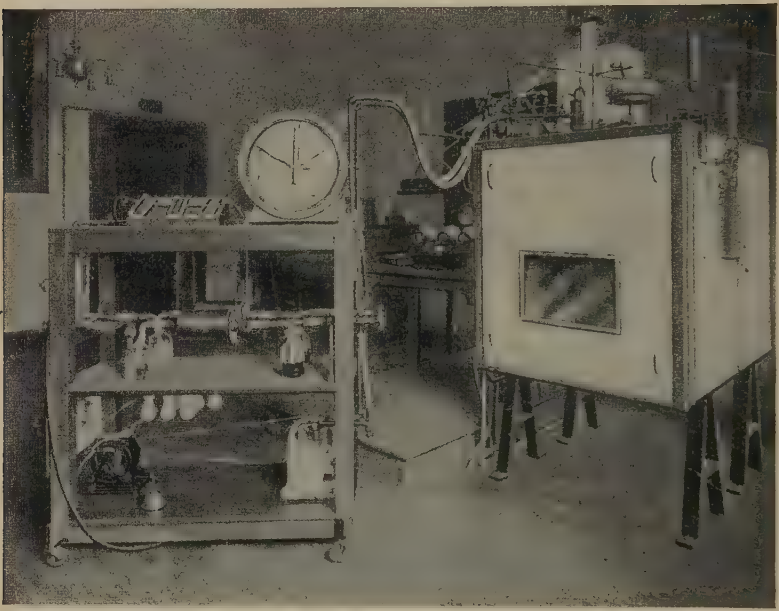

FIG. 221.—Respiration calorimeter. The observations of Howland were made with this apparatus. (Williams, Journ. Biol. Chem., 1912, xii, Fig. 6, Pl. IV, pp. 332 and 333.)

The modification designed by Lavialle consists of a single cylinder which has been calibrated with electric lamps, but the readings of expansion are made from a graduated bell which dips in a vessel of water. Ventillation in both these types is accomplished by the heat of the subject's body, an opening on the under side permitting entrance of the air and one at the top giving it exit. An anemometer is not used but a differential thermometer may be attached as in the *calorimeter à air* used by Bonniot.

It would seem from the description available on the use of this type of instrument that it is capable of giving very accurate results, so far as the measurement of radiant heat or heat of convection is concerned.

The heat lost by evaporation of water seems to be entirely neglected, as well as that which may be stored temporarily in the infant's body. It is the more remarkable, therefore, that even by the D'Arsonval method the measured heat is usually considerably higher than that obtained by the indirect method (Table 25).

As contrasted with these simple calorimeters the instrument designed by Rosa,[4] modified by Benedict,[3] and adapted to the study of infant metabolism by Williams,[206] is an instrument of great precision (Fig. 221). The apparatus is at once a respiration machine giving all the data except nitrogen in the urine, necessary for the calculation of the energy exchange and an adiabatic calorimeter which takes up the heat of radiation and conduction in a coil of running water, the heat of evaporation by gravimetric determination of the water given off by the subject and even the most minute changes in body temperature by means of an electrical resistance thermometer placed in the rectum. In other words, one makes a study of the heat production by chemical means simultaneously with the heat loss by physical means. Only one such study of the energy metabolism in infants has ever been made, namely, that of Howland.[87] This study is classified in the table above with the indirect method for the reason that his published data of the heat as measured (direct) are not complete. Besides, the greater errors are known to be on the side of the direct measurements, notwithstanding all the refinements. Even with babies, however, it is possible to secure results by the two methods which agree very closely. Howland found on six different days the following differences: 2.0, 4.1, 0.7, 1.7, 2.7, 1.8, or an average of 2.1 per cent. This error is less than the average error in the direct method alone.

The features of the apparatus already described (p. 563) for measurement of the energy metabolism of infants by the indirect method are copied after those same features of the respiration calorimeter just considered. Most of the problems of infant metabolism present or future can probably be studied even better with an apparatus of this type than with the respiration calorimeter, although some of them will require the much more expensive installation.

Basal Metabolism.—Three different observers have attempted to secure the metabolism of the infant while fasting. Rubner and Heubner[162] compared the metabolism of a breast-fed infant five and one-half months old and weighing nearly 10 kg. while on full diet four days with his metabolism on the fifth day when he received only tea instead of the breast milk. The metabolism on the day of starvation was even higher than the average of four days on food.

Two objections may be urged against this experiment: First, that no graphic record was obtained to prove that the infant was just as quiet on the starvation as on the food days. It is almost unbelievable that such should be the case. The second objection is that caffein is known to increase metabolism[113] and there is every reason to believe that the closely related *thein* might have a similar effect especially upon an unhabituated infant. Howland[85] tried an experiment in fasting in much the same way with an infant three months of age, and weighing 4.65 kg., giving tea and saccharin instead of one-half milk and 5 per cent. milk sugar which had been the regular food. The result was the same: namely, that the metabolism was not quite as low even when the child was known to be asleep as while sleeping after a feeding. The first objection urged against Rubner and Heubner's experiment would not, therefore, seem to apply, although a graphic record giving proof that sleep while fasting was just as peaceful as after feeding would be required to make the matter wholly convincing. The second objection has not been removed. Schlossmann and Murschauser[178] kept careful and continuous notation of the repose of their infants, and determined the metabolism repeatedly on three different female infants from 87 to 180 days of age 18 hours after last food. All received tea and saccharin which the authors used habitually to soothe their subjects to sleep. The average minimal metabolism of the three was 12.22 gm. CO_2 and 11.02 gm. O_2 per square meter (Meeh) of body surface per hour, or 859 calories per square meter and 24 hours. This is lower than the average obtained by Benedict and Talbot on the six normal infants included in Table 25 most of the observations on which were made within three hours after food, while they were very quiet or actually asleep. The average age of these six infants was 5.4 months, while that of the three studied by Schlossmann and Murschauser was 142 days. Both Benedict and Talbot and Murlin and Hoobler obtained a lower value, however, as an average of their observations on normal infants from two to three months of age.

It will be apparent from this recital that the whole question of basal metabolism is complicated on the one hand by the difficulty of securing perfect repose without an immediately preceding meal, and on the other hand by the question of age. None of the researches yet reported have fulfilled in a wholly convincing manner the conditions now recognized as necessary to secure the absolute basal metabolism of infants. We must be content for the present, therefore, to speak of the lowest metabolism obtainable under the various circumstances as the "minimal metabolism." As landmarks of progress in this direction, the brief table on page 635 may be borne in mind.

It is somewhat hazardous to compare the results of different authors obtained on different subjects by methods which are not strictly alike; but the table suggests, if it does not prove, that the stage of digestion as well as the age of the infant are factors which must be reckoned with in attempting to arrive at truly basal conditions. The environing temperature was different in the three groups of cases cited, but the fact that quiet sleep was induced may be accepted as proof that the clothing was properly adapted to the temperature of the chamber.

We pass now to a consideration of the two factors just mentioned: Namely, (1) the dynamic action of food, and (2) the influence of age upon the metabolism.

Dynamic Action of Foods in Infants.—It will be seen later than the energy metabolism of the infant from two months to one year of age

TABLE 27.—AVERAGE MINIMAL METABOLISM OF NORMAL INFANTS
(All sleeping or nearly quiet)

Authors	Condition	Cases averaged	Age, months	Calories per square meter (Meeh) and 24 hours
Schlossman and Murschauser......	Fasting 18 hrs.	3(S, P, L.)	3 to 6	859
Benedict and Talbot	Post-absorptive (?)*	6(E. F., E. R., A. S., R. A., N. D., B. F.)	2 to 3	809
Murlin and Hoobler	One-half to three hours after feeding	4(A. S., W. I., E. H., E. N.)	2 to 3	843
Benedict and Talbot	Post-absorptive	2(E. G., P. S.)	10 and 12	983
Murlin and Hoobler	One-fourth to 5 hours after feeding	2(C. M., W. S.	10½ and 12	1104

*No details given by authors for three of these infants.

is about two and one-half times that of the adult on the basis of weight. This means that the alimentary tract of the infant must be at least two and one-half times as active as that of the adult in order to supply to the circulation the materials necessary for combustion. Added to this is the requirement for growth. It might be expected *à priori*, therefore, that the proportionately more rapid streaming of materials into the blood (p. 545) would set up a greater dynamic effect in the infant than in the adult. The evidence to date, however, is that the reverse is true.

Rubner and Heubner were of the opinion that they had demonstrated a dynamic effect of cow's milk when they found in their second study a higher heat production in an artificially-fed infant of seven and one-half months than in their first breast-fed infant of nine weeks. Using the latter as a basal experiment, they calculated that a diet of cow's milk containing 44 per cent. more than the maintenance requirement of energy had raised the metabolism in the former 9.7 per cent. The difference in the ages of the two infants together with the absence of certainty that the second infant was not more active than the first wholly invalidates their conclusions.

The dynamic effect of protein in the metabolism of an infant was first proved by Howland. Adding four grams of nutrose (containing 14.25 per cent. nitrogen) to each of three previous feedings increased the metabolism of his first subject, three months of age, 10 per cent. Adding 30 gm. to the food of his second child of seven months raised the metabolism 26 per cent. Murlin and Hoobler saw a similar effect

DYNAMIC EFFECT OF PROTEIN (HOWLAND)

Date	Weight	Food	Calories per hour
Feb. 23, 1911.......	4.32	⅗ cow's milk, 5 per cent. milk sugar	15.35 sleeping entire time
Feb. 25, 1911.......	4.32	Same + 30 gm. Nutrose	19.31 sleeping entire time
		Difference.....	3.96 calories = 26 per cent.

from changing to a richer protein formula the diet of an atrophic infant (C. P. Table 26) three months of age. The nitrogen in the urine rose in response to the greater intake of protein and the heat production was increased more than two calories per hour. The child slept throughout, but made more frequent readjustment movements after the high protein feeding. Hoobler[83] followed up this subject independently and demonstrated a much higher metabolism by feeding progressively higher and higher protein formulæ. The following comparison of the periods on low and on high protein diets summarizes his results on a single subject.

TABLE 28.—DYNAMIC EFFECT OF PROTEIN (HOOBLER)

Number of hours	Food	Degree of repose	Distribution of calories	Calories produced		Increase, per cent.
				Per hour	Per square meter and 24 hours	
5	Low protein......	Sleeping	P, 12.2 per cent.; F, 26.4 per cent.; CH, 61.4 per cent.	10.78	893	
10	High protein..... Albumin-milk	Sleeping	P, 40.2 per cent.; F, 18.7 per cent.; CH, 41.1 per cent.	12.74	1120	25.4

The highest dynamic effect of milk protein ever recorded was obtained on this child on the twelfth day of the special feedings when the amount of protein (in the form of albumin-milk) in the 24 hours food was 43.3 gm. compared with 9.9 gm. in the basal diet. The dynamic effect in absolute terms was 108 calories for the 24 hours or 42.4 per cent.

The dynamic action of fat seems to be proved by the following observations made by Niemann[132] on a normal, though at the time, underweight, child four weeks of age. In one period of four days when the food contained 127 calories from protein, 105 from fat, and 168 from carbohydrate, or 400 calories in all, the average daily metabolism was 521 calories or 1337 calories per square meter of body surface (Meeh). In the following period of five days the food contained 145 calories from protein, 368 *from fat* and 177 from carbohydrate or 629 calories in all. The heat production averaged 569 calories per day or 1443 calories per square meter. An increase of 70 per cent. in the energy intake (largely fat) increased the metabolism 10 per cent. Niemann[133] observed a similar effect of increasing the fat in the food of an atrophic infant 22 weeks old.

The writer is not aware of any experiment establishing the dynamic action of carbohydrate in infants (p. 609).

The dynamic effect of a large feeding contrasted with a small one, without special reference to the separate organic constituents is discernible in the tables given by Murlin and Hoobler. One of these is shown in Table 26. Child 2, because he had not previously slept more than one hour in the respiration chamber on Feb. 17 was given two of his usual feedings only 15 minutes apart. This time he slept nearly through the second hour, but produced two and a half calories per hour more than he had produced on Feb. 14th when the feedings were two hours apart, or on Feb. 16th when only one feeding was given.

The evidence of dynamic action thus far applies only to surplus food. There is no satisfactory evidence that an ordinary feeding given at the time when the infant is naturally ready for it raises the metabolism at all. In the first place the difficulty of securing perfect repose when the infant is hungry has thus far foiled all efforts to get a clean-cut contrast before and after an ordinary feeding. Although Schlossmann[174] states in one place that the effect of a meal may be discerned as long as 18 hours afterward, yet as already noted (p. 633) neither Schlossmann and Murschauser nor Rubner and Heubner nor Howland were able to demonstrate a lower metabolism in fasting. Benedict and Talbot likewise assert that in some instances the heat production (based on carbon dioxide) in their subjects 21 hours after food was slightly greater "even in periods of complete muscular repose[22] than immediately after food." At times in their tables also (*e.g.*, P. S., Table 23) the carbon dioxide falls progressively, in periods of no greater degree of repose, with the distance from feeding time; but just here lies the fallacy of basing heat production upon carbon dioxide without exact knowledge of the respiratory quotient for the time; for a fall in the quotient in succeeding periods after feeding milk is to be expected. The oxygen absorption, however, may rise at the same time (*e.g.* Child 3, C. P. Table 26, this Chap.) and it is well known that oxygen is a better index of heat production than carbon dioxide. In some cases Benedict and Talbot were able to note an increase of heat production (based on carbon dioxide) "soon after feeding," of from 5 to 10 per cent. above that obtained 18 to 21 hours after food in the same subject. Hellesen[71-a] determined the resting metabolism of a normal infant five months old and found that when a part of the carbohydrate of the diet was replaced by an isodynamic amount of fat the heat production was increased 8.3 per cent. Schlossman made a similar substitution in kind though not in amount and observed an increase in the metabolism of 15 per cent. (see section on metabolism from weaning to puberty p. 668).

Respiratory Quotient.—This is a convenient place to consider briefly the respiratory quotient. Very little need be added to what was said under this heading for the newborn. Carbohydrate is the food which influences the quotient most. Soon after a feeding of milk, whether breast or cow's milk, the quotient will be found higher than just before, provided the feedings are two hours or more apart, and if easily assimilable sugars are added to the milk the quotient will be even higher. For example: An infant four months of age was given a dextri-maltose formula and the respiration experiments were begun on different days at successively longer intervals from feeding with the following[126] results:

Time after feeding	R. Q.
18 minutes	0.79
33 minutes	0.82
1 hour and 30 minutes	1.00

From this point the quotient usually falls progressively (p. 583). Benedict and Talbot's[22] data show many cases like the following:

Case	Time after feeding	R. Q.
F. B.	6 to 7½ hours	0.80
	20 to 22 hours	0.78
	25 to 27 hours	0.73
R. E.	6 to 8 hours	0.82
	18½ to 21 hours	0.74
	24 to 26½ hours	0.72

Schlossmann and Murschauser, however, often found quotients as high as 0.84 and 0.85 as much as 18 to 20 hours after last food. No details regarding the composition of the food taken at the last feeding are given.

The fact that the respiratory quotient is higher soon after a meal (and progressively falls from a point which may be placed at one to two and one-half hours thereafter depending on the formula) does not denote accelerated heat production, for it will be remembered that carbon dioxide has a lower heat value when the quotient is high than when it is low (p. 587).

Another reason why an ordinary feeding of milk does not raise the heat production* in an infant is the interesting fact first recognized by Rubner that protein retained for growth does not raise the heat production. In truth one can say that any foodstuff retained for growth does not raise the heat production. It is only when a surplusage of digestive products enter the circulation that oxidation of them is accelerated by adding more fuel to the fire or by stimulating the intracellular processes. In the infant or any other stage of active growth (pregnancy or convalescence), the materials entering the circulation are retained with greater avidity by the cells and therefore are not exposed to the destructive oxidations to the same extent as in the normal adult. Hoobler[83] has made this point as regards protein an object of special study in an infant, with the following results:

	Protein Ingested, Grams	Protein Destroyed, Grams	Protein Added to Body, Grams	Calories of Metabolism
Period I	33.1	18.0	15.1	363
Period II	43.3	18.9	24.4	363

Influence of Age on Basal Metabolism.—Basal metabolism is the term used to describe the fundamental requirements of the body for energy when it is resting, fasting, and kept comfortably warm. It is the lowest normal metabolism. With the infant this lowest metabolism will always occur during sleep and at that distance from feeding time just preceding the point where hunger becomes so acute as to induce crying or some other form of activity.

In connection with the dynamic action of food we have chosen to speak of the lowest metabolism yet attained as the minimal rather than the basal metabolism; for we have yet much to learn of the details of this subject. However, the minimal metabolism ordinarily seen in the infant, *i.e.*, the sleeping metabolism, of the recently fed infant, cannot be much greater than the basal metabolism if food really exercises so small an influence on total heat production as it seems to. We shall not go far wrong then in speaking of the minimal metabolism observed in infants of different ages as the true basal.

It is now fairly established that this basal requirement varies with age. In a later section we shall discuss once more as it applies to infants up to one year of age the question whether surface area or weight is the better measure of metabolism. For the time being relying on the conclusions of Harris and Benedict (p. 548) from their biometric study of adults and newborn infants we may assume that surface area is at least slightly better.

Benedict and Talbot first demonstrated the influence of age on the metabolism per unit of area (Meeh), although not recognizing the fact, in the following table:

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* It would not be correct to say "metabolism," for the synthetic side of metabolism (anabolism) is growth.

TABLE 29.—HEAT-PRODUCTION PER SQUARE METER OF BODY-SURFACE (MEEH FORMULA) FOR NORMAL INFANTS

Subject	Body-weight without clothing, kg.	Height, centimeters	Age	Experimental days	Periods	Heat per sq. m. of body-surface (Meeh) calories per 24 hrs.
M. D.	3.99	..	17 days	2	4	656
L. L.	5.13	57	2½ mos.	10	13	759
B. D.	4.90	58	2 mos.	2	4	802
M. C.	6.17	63	4 mos.	3	7	837
L. R. B.	5.99	64	4 mos.	4	11	844
E. G.	9.37	74	10 mos.	3	5	907
R. L.	7.58	71	8½ mos.	5	8	991
P. W.	7.11	64	7 mos.	2	5	998

The next year Murlin and Hoobler brought together their own data from normal infants and those of Benedict and Talbot published in their second paper[21] and conclusively showed that both on the basis of surface area and weight the metabolism of infants above six months of age is significantly higher than that of infants four months and less. The results are condensed in the following table:

TABLE 30.—BASAL HEAT PRODUCTION FROM TWO MONTHS TO ONE YEAR OF AGE

Months	2	3	4	6	7	9	10–11	12
Calories per hour and square meter (Meeh)	34.7	33.2	36.0	40.2	41.6	41.7	41.8	46.4
Calories per hour per kilogram	2.43	2.29	2.4	2.56	2.57	2.36	2.34	2.61

More recently this difference has been confirmed by Benedict and Talbot[24] who have accumulated data up to the age of puberty.

Surface Area Versus Weight as a Measure of Metabolism.—Previous to the publication of the most recent researches on infants it had been supposed that the metabolism is proportional to surface area regardless of age. Now that it is known to vary with age, the question may fairly be raised whether it is worth while longer to use surface area as a measure of energy requirement rather than weight. The status of the matter may be illustrated by the following table from Murlin and Hoobler.

Here it is seen that on the basis of weight the metabolism of infants from two months to one year of age is less variable than it is on the basis of surface. One must be on guard here against the hasty conclusion that metabolism in general is more nearly proportional to weight.

Table 31.—Summary of Sleeping Periods Showing Relation of Heat Production to Body Weight and Surface Area (Meeh)

Name	Nutritive condition	Age, months	Average net weight, grams	Calories per hour	Number of periods averaged	Calories per kilogram and hour	Calories per square meter (Meeh) and hour
A. Sa.	Normal; overweight	2	5730	13.16	4	2.30	34.73
W. L.	Normal; slightly below average weight	2	4362	10.68	3	2.45	33.80
E. H.	Normal; average weight	2½	4673	12.58	4	2.71	37.84
E. N.	Normal; underweight	3	4132	10.65	4	2.59	34.99
C. P.	Atrophic	3	2488	7.32	4	2.94	33.50
C. D.	Normal; underweight	4	3410	10.24	3	3.00	37.60
M. Me.	Normal; (?) positive v. Pirquet; average weight	5¾	6456	16.62	4	2.56	40.21
C. Ma.	Normal; overweight	10½	9424	24.26	3	2.49	45.74
W. So.	Normal; average weight	11½–12	9456	24.70	3	2.51	46.41
J. Sm.	Normal (?) very much underweight	12	5757	20.16	2	3.51	52.80
	Mean of all cases					2.75	39.76
	Mean omitting J. S.					2.63	38.31
	Mean deviation					±0.163 (6.2%)	± 3.87 (10.1%)

Taking the entire group of nine children in the table, or any other number of like range in age, weight is a more constant divisor. But this would not be true of any given age group. We have just seen (Table 30) that the average heat production of children above six months of age is higher both on the basis of surface and of weight than is that of children from two to four months inclusive. Attention may now be directed to the quantitative relationships between these groups.

Table 32.—Average Heat Production

	Per Square Meter (Meeh)		Per kilogram of weight	
	Calories per hour	Mean per cent. deviation	Calories per hour	Mean per cent. deviation
2 to 4 months	35.4	5.4	2.38	8.0
6 to 12 months	41.9	5.7	2.45	6.5

The percentage deviation for each age group is greater on the basis of weight than on the basis of surface which means that surface is a more constant measure; or that, within each age group, metabolism is more nearly proportional to surface. A sufficient number of observations for treatment by the statistical method is not yet available, but in all probability a larger number will show the same relationships as were found for the newborn infant (p. 601); namely, that: (1) Surface is a slightly better measure of basal metabolism than weight, and (2) it makes little difference which formula is used to express the surface.

As a practical consideration for the feeding of children it may be emphasized: (1) that weight (as shown by the data thus far considered) is a little better measure than surface when children of all ages are considered; and (2) that for children of the same age or *for any group not differing among themselves very much in weight there* is little to choose between surface and weight.

A great deal of confusion has been created by the failure to recognize the truth of the second statement. It follows from the mathematical relationship between weight and surface that it makes no difference which of the several formulæ is employed to express the relationship. Harris and Benedict have rendered a service to the science of metabolism and nutrition in calling attention to the fact that since surface is usually expressed as a quantity in which the two-thirds power of the weight enters as a factor, it must of necessity be less variable than the weight, but they announce with an apparent air of triumph the discovery that surface after all is only a little better measure of metabolism than weight. As a matter of fact, from the very mathematical relationships it could not be a very much better measure as between individuals which do not differ much in size. Some illustrations will make this clear. Suppose we have two infants weighing 7 and 8 kg. respectively. Expresssing their weights in grams and their surfaces by Meeh's formula in square centimeters, we have these proportions:

Weights	Surfaces
7000	4354
8000	4760
7000:8000::0.88:1	4354:4760::0.91:1

That is, if we had two values for the heat production of these two infants, say 880 and 1000, which were exactly proportional to their weights, they would be at the same time *almost* proportional to their surfaces and *vice versa.*

Taking two children weighing 20 and 21 kg., we have the following:

Weights	20,000:21,000::0.95:1.00
Surfaces	8768: 9058::0.97:1.00

or two youths weighing 40 and 41 kg., and we have

Weights	40,000:41,000::0.98+:1.00
Surfaces	13,920:14,150::0.98−:1.00

Here the two measures are of exactly equal value to 2 places. Neither weight nor surface could be a better or a worse measure of metabolism.

Contrast with this, however, the relationships when weights are farther apart. If we have two individuals weighing 4 and 40 kg., or, still better, a newborn child weighing 3.5 kg. and a man weighing 70, then,

Weights	4: 40::0.1 :1	3.5: 70::0.05 :1.00
Surfaces	2999:13,920::0.21:1	2743 :20,210::0.135:1.00

In the one case the weight of the older is ten times that of the younger, and in the other it is twenty times, while the surface is less than five times in one case and about seven in the other. Surface, therefore, might be twice as good a measure of metabolism as weight, as between the first pair, and nearly three times as good as between the second pair of individuals. From purely mathematical considerations it might also be twice and three times as bad a measure. As a biological fact now well known, however, it is better, *i.e.*, heat production is *much* more nearly proportional to the surface than to weight in animals of the same species but of widely different size.

In the judgment of the writer it is grossly incorrect to suppose that physiologists have believed the metabolism to be absolutely proportional to surface regardless of circumstances. Rubner[154] for the German literature and Richet[148] for the French are responsible for the first demonstrations of the applicability of the law. Rubner worked with dogs of adult stature but widely different size, estimating their metabolism by the indirect method. Richet worked first with rabbits ranging from 2,000 to 3,000 grams in weight but he determined only the heat of radiation and conduction, neglecting, as all subsequent French observers have done, the heat given off by evaporation. Naturally his quantities would be more nearly proportional to surface than the total. However, in the estimation of surfaces he says, "if one supposes that animals of different size are like spheres of different volumes, then the respective volumes are among themselves as the cubes of their radii; while the respective surfaces are among themselves as the squares of their radii. These considerations apply to living animals, and, since their form is so irregular compared with that of a perfect sphere, one can only apply the geometrical facts to them *approximately*." Further in summing up the factors which determine heat production Richet notes that one of these is "the nature of the integument."[148] In two important respects, therefore, Richet made saving clauses regarding the application of the law of surface, one concerning the measurement of surface and the other concerning the nature of the skin, meaning, of course, its conducting properties. Rubner in the beginning considered that he had demonstrated the law only for adult animals and later in applying it to children made this very emphatic reservation: "The law of surface area holds under all physiological conditions of life, but for its proof it is a reasonable presumption that only organisms of similar physiological capacities, as regards nutrition, climatic influences, temperament, and functional power, should be compared.[160] Other students of metabolism who have really understood the law have made similar reservations. Thus Schlossman says, "the presumption is on the one hand that the environment is relatively normal, on the other that the child has a relatively normal surface, that is, a functioning and good conducting skin with the normal amount of subcutaneous fat."[175] Otherwise the law could not be expected to apply.

We must distinguish clearly the arguments against the law of surface as of two classes: (1) On the basis of fact and (2) on the basis of explanation. The arguments against the law, so far as they rest upon facts, as we have just seen, seem to have been misconceived. It never was supposed by its chief proponents that the law would apply to all physiological and pathological conditions but only to similar physiological (normal) conditions. Also, a very superficial understanding of the necessary mathematical relations shows that the law has natural limitations which must be recognized if one is to avoid compromising it with impossible conditions.

The arguments against the law on the philosophical basis are more difficult to meet. There is no doubt that Rubner, following Bergmann, has conceived of the law as causally related to Newton's law of cooling. This dependence as commonly accepted may be phrased in this way. Solid bodies when warmed lose heat in proportion to their surfaces. Since the heat production of animals seems to be proportional to surface area, it would seem to follow that heat is produced *in order to* replace that which is lost or *to maintain* body temperature. It is the teleological aspect of the case which has called forth most criticism. To say that heat is produced at such and such a rate *in order that* body temperature must be maintained denotes, some say, an all too naïve conception of nature. Blood does not coagulate in order to prevent hemorrhage, but because certain chemical agents are present and have certain properties. The fact that it does stop hemorrhage is quite incidental. It may indeed have selective value, so that a species whose blood did not clot would have the worst of it in the struggle for existence, but it will never do to say that this chemical physiological function originated for the purpose of preventing hemorrhage; for that would imply a mind at work in anticipation of the result. So also with heat production. These critics, of whom Kassowitz has been chief, prefer to account for heat production in a perfectly causal manner. "Small animals maintain a higher rate of oxidation, it is true, than large ones, but this is not because they lose heat more rapidly in consequence of greater (relative) surface, but because their alternating movements (later phases caused reflexly by earlier phases) follow one another more rapidly on account of shorter nerve paths.[92] Kassowitz indeed finds that the higher rate of oxidation in small, warm-blooded animals has even for them "dysteleological consequences; for because of the more extensive muscular contractions more food and reserve substances are placed in requisition and by this means the deposit of reserve fat in the whole body, and especially in the subcutaneous tissues, is made more difficult, so that the protection against cooling—which a thick layer of fat prevents—fails in part amongst the very animals which need it most."[93] Even Kassowitz is obliged to admit, however, that "in warm-blooded animals which are in a position to maintain their own body temperature under the most diverse conditions, one can claim the appearance of some justification that their living parts produce heat in order to protect the body against loss by radiation, etc."[93] Whether this is a real justification or only the appearance of one will not trouble the practical pediatrist so long as the generalization that human beings of widely different size produce heat in proportion to surface rather than weight, and therefore require food energy in this proportion, helps him to understand his feeding problems; and there is no doubt that the law of surface area has been immensely useful in this connection. It explains the much higher requirement per unit of weight of the young individual in comparison with the adult, better than the so-called causal explanation cited by Kassowitz. It explains also much better the need for conservation of heat in the infant, and the role which subcutaneous fat plays in this connection.

The Rôle of Body Fat.—As between two infants of the same age, one fat and the other thin, the latter consumes more food per unit of weight, and if the difference in subcutaneous fat is great, more also per unit of surface as this is given by the several formulæ. Aside from hereditary influence on the body size, the chief cause of difference in weight of normal infants at birth or, for that matter, at any other given age, is the proportion of fat, which, in turn, is determined by the nutritive condition. We must now face the question whether this fat deposited for the most part beneath the skin, reduces the metabolism per unit of weight because it protects against the heat loss by radiation and conduction, or because it serves as so much ballast, so to speak, thereby cutting down the proportion of active tissue where heat is produced. The question is not a new one. It has, in fact, been raised wherever marked discrepancies have been found in the application of Rubner's law of surface area. Rubner[155] himself, when he first observed such discrepancies in the application of the law (at that time but recently demonstrated for animals) to human subjects of different ages, hinted at a difference of functional capacity, but dismissed the idea as one of minor importance. Magnus-Levy and Falk,[109] however, in their study of the influence of age on the respiratory metabolism, very clearly expressed the possible significance of differences in this proportion. "We shall not go far wrong," they say, "if we absolve entirely from any true participation in the (energy) metabolism the fat laid down in the connective tissues and nervous system as dead reserve, if we ascribe only a little to the bones and connective tissue frame-work, and recognize the greatest contribution to energy transformation as coming from the tissues richest in protoplasm, the muscles, glands, and so forth." In another place Magnus-Levy expresses the opinion that we "must take into account the mass of active protoplasm present in different persons." Hösslein[84] goes so far as to say "the metabolism is nearly proportional to the volume and vital energy of the muscles" and he explains the Bergmann-Rubner law on the ground that the mass and development of the muscles increases in the animal kingdom almost *pari passu* with the superficial area of the body." This is substantially the position taken by Benedict and Talbot. Comparing the metabolism under minimal conditions of sixty-one different infants[21] varying in nutritive conditions from extreme atrophy to very much overweight, and in age from a few hours to 17 months, they find no parallelism between the heat production and body surface as given by any of the formulæ in use at that time, and none between heat production and body weight. They conclude that it is "the active mass of protoplasm which determines the fundamental metabolism." Curiously enough, these authors appear to regard their findings as a crucial test of the law of surface area; whereas the conditions necessary for its proof, recognized by Rubner[160] were not in the least complied with.

By reference to the charts on pp. 665 and 666 it may be seen that in general atrophic infants have a higher metabolism than infants of normal weight and infants of overweight a lower metabolism than either. The presence of fat always lowers the metabolism per unit of weight and according to either the Meeh or Lissauer formula it frequently reduces the metabolism also per unit of surface; while its absence produces the opposite effect. Are these facts to be explained by the replacement of active tissues by fat or to an effect of fat upon the heat loss?

A study of the chemical composition of fat and atrophic infants' bodies compared with infants of normal weight should throw some light on this question. The following table gives the latest analyses available.

TABLE 33.—COMPOSITION OF INFANT'S BODY COMPILED FROM VARIOUS AUTHORS

Author	Condition	Age	Weight	In 100 parts				
				Water	Dry substance	Ether extract	Ash	N
Camerer and Soldner.*	Normal newborn	Average of six infants at term.	2820	71.8	28.2	12.3	2.7	1.8
Sommerfeld†......	Normal infant	3 mo.	4340	70.15	29.85	13.4	2.73	2.27
Steinitz No. III...	Atrophic infant	3 mo.	2625	79.9	20.1	1.45	2.73	2.3
Steinitz No. IV....	Atrophic infant	2½ mo.	1960	82.3	17.7	1.8	3.2	2.13
Steinitz No. V......	Atrophic infant	3¾ mo.	3220	79.8	20.1	1.98	3.34	2.51
Steinitz and Weigert............	Fat infant‡	4 mo.	3711	58.94	41.06	244.17	2.98	2.29

It is obvious from these figures that fluctuations in the amount of fat are offset by fluctuations in the content of water; in other words, fat, instead of replacing protein or being added to the other constituents of the body, actually replaces water, leaving the percentage of protein (active tissue?) the same.

From the charts (Figs. 223 and 224) and from the data presented in Table 30 we have abundant evidence that the metabolism increases rapidly from birth to at least one year of age. The difference in nitrogen content of the infant's body from birth to 2, 3, and 4 months of age as given in the table is due in the main to loss of water. This is suggested also in Niemann's[132] study of the water metabolism of the same infant at various points from 16 to 42 weeks of age. It would seem therefore that the coincident increase in metabolism may be explained by a loss of water and a consequent gain in the metabolic activity of the protoplasm.

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* Camerer and Soldner: Ztschr. f. Biol., 1902, xliii, 1.

† Sommerfeld: Arch. f. Kinderh., 1900, xxx, 253.

‡ This child had been fed by its mother on gruels containing a large preponderance of carbohydrates.

But the constancy of the protein content between children of the same age (nearly) but of different nutritive condition seems to make it clear that the proportion of active protoplasm *as compared with fat* can not be the cause of the observed differences between thin and fat children. Nitrogen content is the best criterion we have at present of the protoplasmic mass.

Benedict and Talbot[22] present the following very interesting table comparing the metabolism of infants of different ages but of approximately the same weight and height. In every instance the older infant has the higher metabolism.

Table 34.—Comparison of Heat Production of Infants of Like Body-weight and Height, but of Different Ages (Benedict and Talbot)

Subject	Sex	Body-weight, kilograms	Height	Age, months	Heat produced		
					Per 24 hours, calories	Per kilogram per 24 hours, calories	Per square meter (Meeh) per 24 hours, calories
A. L.	F.	3.18	53	4	226	71	876
J. V.	F.	3.38	53	8½	297	88	1108
E. N.	F.	5.40	66	6	353	66	962
D. M.	M.	5.18	66	11	369	71	1034
M. M.	F.	5.47	62	4½	285	52	770
J. M.	M.	5.63	62	8	467	83	1239
D. Q.	M.	5.28	62	4½	305	57	846
J. P.	M.	5.45	63	7	387	70	1039
M. M.	F.	5.47	62	4½	285	52	770
J. P.	M.	5.45	63	7	387	70	1039
D. Q	M.	5.28	62	4½	305	57	846
J. M.	M.	5.63	62	8	467	83	1239
L. R. B.	F.	5.99	64	4	331	55	844
F. K.	M.	5.71	65	7	381	67	1003
H. T.	M.	9.33	75	5½	420	45	797
E. G.	M.	9.37	74	10	479	51	907

Their explanation was that the older infant having a deficiency of fat had therefore a greater proportion of active protoplasmic tissue. But if fat merely replaces water this can scarcely be the true explanation. The table can be used equally well to prove that the older infant has a specifically higher metabolism (which the authors now believe) or even to prove that the heat production is greater because the heat loss is greater. But for this purpose infants of the same age and of different weight (because of fat) should be chosen (as *e.g.*, p. 653, Table 37).

We must now consider the effect of the absence of fat.

Metabolism of Atrophic Infants.—In 1877 Parrott[137] applied the term athreptic to all infants showing a retardation of development from any cause. By primary infantile atrophy or marasmus is generally understood today something more specific than this. There is emaciation with loss in weight often far below birth-weight and the cause is a primary failure of nutrition. The loss of vitality which ultimately ensues carries with it a failure of heat regulation and a consequent subnormal temperature. The metabolism of such cases uncomplicated by demonstrable infection should be considered at this point in comparison with that of the normal infant, because of the special interest attaching to the role of body fat. Here we have infants often utterly devoid of fat. What effect does fat as an insulating medium have upon the heat production and therefore upon food requirement?

In Table 35 are brought together all the known researches upon any phase of the energy metabolism of the truly atrophic infant.* These fall very naturally into two groups which may be distinguished at a glance by the level of metabolism whether on the basis of weight or surface. The all-day experiments of Rubner and Heubner,[162] Niemann,[133] Bahrdt and Edelstein,[6] and Frank and Wolff[59] include all the effects of muscular activity, crying and mere restlessness inherent in the life of an infant three to eight months of age; while the short-period experiments of Howland,[85] Benedict and Talbot,[22,21] and Murlin and Hoobler[126] eliminate the activity factor more or less completely by taking the metabolism only during quiet sleep or periods which approach this state of repose. There is a difference of fully 100 per cent. between the lowest sleeping metabolism (Howland's case) and the highest metabolism (Niemann). There is, however, as would be expected, with a sufficient number of cases an easy gradation from one group to the other with the mean lying at about 1,000 calories per square meter of surface (Meeh). The lowest all-day result (Rubner and Heubner) coincides with the highest minimal activity experiment shown in the table (Benedict and Talbot).

The influence of age is also readily discernible. The oldest child used in the all-day experiments gave a result which is probably the highest (average) in the table (Bahrdt and Edelstein) and the youngest child of this group gave also the lowest metabolism (Rubner and Heubner). At the middle-range the relationship to age is obscured a little. One of Niemann's five and one-half month's children gave a metabolism lower than that of the four and one-half month's infant of Frank and Wolff. This difference is undoubtedly due to a large extent to the difference in dynamic effect of the food. Frank and Wolff gave their infant "Eiweissmilch" which as already noted (p. 636) in the case of Hoobler's three months infant gave a marked dynamic action; while Niemann gave his smaller infant expressed nurse's milk which would have a minimal dynamic effect compared with cow's milk (II infant). With this single exception the results arrange themselves according to

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* The contribution of Schlossmann[174] is omitted because his infants as shown by Kassowitz[93] were really convalescent at the time of observation.

TABLE 35.—ENERGY METABOLISM OF ATROPHIC INFANTS

Indirect Method

Author	Date	Type of apparatus	Number or name period	Age, months	Weight, grams	Condition	Food	Per kilogram and hour		Calories	
								CO_2	H_2O	Kilogram and hour	Per square meter (Meeh)
Rubner and Heubner...	1899	Pettenkoffer-Voit, entire day	Child P, 1st to 4th day	3½	3000	Moderately atrophic	950 gm. ½ milk and milk sugar	1.46	2.31	3.99 max.	1090–1171
Poppi................	1900	Closed circuit	7	3½–16	2780	All atrophic	No details	0.68–1.28			
Howland..............	1911	At-R-B †calorim. hourly periods	Child 3	6	3050	Very atrophic sleeping	⅖ milk and milk sugar	1.09	....	2.57	729
Niemann..............	1913	P-V, mean of 5 days	I child K	5½	3000	Very atrophic; no abnormalities; good growth	600 gm. express nurse's milk	1.43	4.02	4.29 max.	1164–1277
			II child Sch	5½	3100	Atrophic; probably premature	900 gm. ½ milk	1.56	1.51	5.05	1336–1519
Bahrdt and Edelstein...	1913	P-V, entire day	H. V., 2- to 4-day periods	8	5127	Atrophic, scanty growth	980 gm. ⅔ milk, 5 per cent. Soxhlet sugar	1.24	1.64	4.22	1470
Frank and Wolff.......	1913	P-V, entire day	H. G., 5th to 8th days	4½	3650 3180	Moderately atrophic	800 gm. "Eiweiss milch"	1.68	....	4.60	1431
Benedict and Talbot...	1914	Cl-cir., short periods	E. H. S.	3½	2960	"Infantile atrophy;" minimal metabolism	Fed within 3 hours	0.96	....	2.70	783
			E. S.	4	3170		Fed within 3 hours	0.98	....	2.79	829
			K. R.	5	2990		Fed within 3 hours	1.15	....	3.12	911
			L. O.	6	3180		Fed within 3 hours	1.23	....	3.41	1008
Murlin and Hoobler....	1915	Cl-cir., hourly periods	C. P., average of four 1-hr. periods	3	2488	Marked condition of atrophy sleeping	Fed dextri-maltose formula ¼ to 1 hour previously	0.86	....	2.94	804

Direct Method

Authors	Date	Type of apparatus	Number or name	Age, months	Weight, kilograms	Condition	Food	Calories per kilogram and hour
Saint-Albin............	1904	Richet calorimeter	33	Not given	2–9.3	No details	No details	11 above normal* 11 below normal 6 normal
Variot and Lavialle........	1912	D'Arsonval calorimeter modified by Lavialle	6	3–7	2.72–4.25	No details	No details	3.5–6.0

* Normal as given by Langlois (see text). †At-R-B = Atwater-Rose-Benedict

age as well as could be expected where no record of muscular activity was kept.

In the short-period work (with the exception of Howland's case) the influence of age again is evident. Taking the four cases of Benedict and Talbot (selected from their table as their only clear-cut instances of primary atrophy) a very striking gradation running upward with age is presented. The four varying in age from three and one-half to six months differ among themselves only 220 gm. at most in weight. Since from the authors' description no other criterion of the relative stage of atrophy is distinguishable it may be assumed that this gradation is really, at least in part, due to age. It is very difficult to compare different cases however even with the help of copious notes, so that no dogmatic position can be taken from the data now at hand. It may be safely asserted only that *most of the differences* in metabolism presented by this exhibit of atrophic infants can be accounted for by the now well-established factors of metabolism.

Something remains to be accounted for by the stage of atrophy itself. Certainly Howland's case six months of age described as "literally skin and bones" was a more advanced stage of marasmus than Benedict and Talbot's case of the same age described as "a very much underweight and undernourished infant" who, "taking into account his subnormal temperature, general appearance and history, might be considered a case of infantile atrophy." The difference in metabolism is quite too great to be accounted for by any difference in activity or food detectable in the records. The difference in weight also is negligible. It may be stated with assurance that in the last stages of marasmus the metabolism is much below normal. This factor doubtless plays its part in the higher level of metabolism attained by Frank and Wolff's infant described as "moderately atrophic," than that attained by Neimann's first subject one month older and described as "very atrophic." The difference in weight bears out the description.

Proceeding to the second part of Table 35 it will be noted that there are two important researches on atrophic infants one by each of the well known French methods. The work of Saint Albin[168] using the Richet calorimeter is more extensive; but the results of Variot and Lavialle[196] obtained with the D'Arsonval *thermo-electrique* calorimeter, Lavialle modification, are probably more reliable (p. 632). Saint Albin gives his results in relative terms basing them upon Langlois' standard of normal metabolism (Table 25). This standard, as pointed out by Variot and Lavialle, is too high because Langlois, following Richet, worked with nude infants exposed to a temperature which at the beginning of an observation was never above room temperature. If a normal standard is used it is found that all of Saint Albin's cases, instead of only one-third of them, are above normal. The results of Variot and Lavialle are also much above what they consider normal (Table 25).

Unfortunately it is impossible to compare the metabolism of Saint Albin's atrophics with their normal prototypes except upon the basis of weight. Variot and Lavialle on the other hand actually measured the surface area of their atrophics, according to the method of Roussy[153] (Fig. 200) and compared them with normal infants. The following are selected from their tables.

TABLE 36.—HEAT ELIMINATION OF NORMAL AND ATROPHIC INFANTS (VARIOT AND LAVIALLE)

Name	Age, months	Weight, grams	Surface (Roussy)	Calories per hour	Calories per kilogram and hour	Calories per square meter and hour
Normals						
C.	5	5800	0.294	20.0	3.1	68
B. F.	5½	7000	0.306	22.0	3.1	72
Atrophics						
F. P.	5	4250	0.222	19.0	4.5	79
M. J.	5	3950	0.230	16.0	4.1	70
R. L.	6	2860	0.192	14.5	5.0	75
F. E.	7	3740	0.201	17.8	4.76	87

Here we have normal and atrophic infants of the same age, giving as would be expected, widely different levels of metabolism per unit of weight. The surfaces given are not derived from a formula based upon weight or weight and height but are probably much more nearly correct. It is particularly interesting for this reason to find the metabolism *so nearly* the same per unit of surface for atrophics as in the normals. The corresponding means for all the cases reported by Variot and Lavialle are 72 calories per square meter per hour for normals and 74 for atrophics. In this comparison however age is not taken into consideration. The normals are of a higher age than the atrophics. It is as certain therefore as can be from the data before us that heat elimination as measured by the D'Arsonval calorimeter is somewhat higher for the atrophic infant on the basis of a square meter of surface than it is for the normal infant, of the same age.

To get the full significance of this fact it is necessary to recall briefly the circumstances of the experiment as it is carried out with the D'Arsonval instrument. The infant is clothed. He lies on a shelf elevated above the floor of the chamber. The air enters below, circulates through the chamber, first below then above the subject and leaves by an aperture at the top. The heat eliminated by the child is carried away partly by convection, *i.e.*, is conveyed by the air current, and partly by radiation and conduction. The former may be measured by reading the velocity of the air current; the latter by noticing the expansion pressure exerted by the air contained between the walls of the chamber (p. 632). By far the largest part of the heat comes from the skin; a small part (exactly how much the experimental procedure does not enable one to say) from warming of the inhaled air.

Whatever this fraction may be it certainly would not be greater for atrophic infants, in whom atalectatic spots are frequently found in the lungs, than in normals. Probably it is much less. More heat per unit of surface from an atrophic infant therefore would mean more heat coming through the skin. Is this quantity greater because the atrophic infant has more active protoplasm to produce heat? Nobody who has ever seen an infant such as Howland describes can think for one moment that this is the case. There is certainly very much less muscle, for example in the five months-old atrophics in Table 36 than in the normals of the same age. The only satisfactory explanation is that more heat escapes because the means of escape is easier—the skin has no fat underneath it to act as a conserver of body heat. And if the body temperature is kept up it is because more heat is produced in answer to the greater loss. As a matter of fact it is well known that a subnormal temperature is often encountered in these infants, because of the excessive heat loss.

As already noted (p. 630), the experiments by the direct (French) methods are not strictly comparable with the indirect methods because no account is taken in the former of the change in body temperature from beginning to end of an experiment and the heat lost by evaporation of water is not reckoned in. The higher metabolism by the direct method therefore is somewhat surprising. So far as the metabolism per unit of weight is concerned it may be accounted for in part by the lower temperature at which the experiments were conducted (*e.g.*, 10°C. in Variot and Lavaille's experiments, 20°C. Benedict and Talbot; 28°C., Murlin and Hoobler). We shall consider presently the influence of external temperature. Meantime it may be emphasized that there is an even greater difference between the direct and indirect methods on the basis of surface and that the reason for this is that Variot and Lavaille found the surface to be much smaller both for normals and atrophics by the method of Roussy than is given by the Meeh or even the Lissauer formula. Just how much reliance can be placed upon the Roussy method only a great addition to the number of actual measurements now available can finally decide. It is worthy of note, however, that the evidence from this method, such as it is, directly controverts the supposition of Schlossmann, Bahrdt and Edelstein and Frank and Wolff that the surface as given by the Meeh and Lissauer formula is too small, and that the apparent increase in metabolism of the atrophic is to be explained in this way. When the surface area of atrophic infants as compared with normals of the same age is accurately known it will probably be found that the metabolism on this basis is increased even more than has been indicated above. In the following comparison it would be well to bear in mind that there is more reason for thinking that the actual surface of an atrophic infant is decreased in proportion to weight than for the opposite assumption.

On page 647, Table 34, were brought together for comparison the metabolism of infants of the same weight and height but of different ages and it was seen that in every case the older child has the higher metabolism, from which it has been argued that the metabolism is determined by the mass of active protoplasm. Since we now know, however, that metabolsim varies with age even on the basis of surface area it will be of advantage to compare infants of the same age but of different weight, in the same way. The cases given in Table 37 are compiled from the same source as those in Table 34.

TABLE 37.—METABOLISM OF INFANTS OF THE SAME AGE BUT OF DIFFERENT WEIGHT (NUTRITIVE CONDITION) (FROM BENEDICT AND TALBOT)

Name	Age, months	Weight	Height	Metabolism		
				Per day	Per kilogram and hour	Per square meter (Meeh) and 24 hours
E. R.	3	4.47	55	286	63	873
E. F.	3	7.07	62	311	44	708
A. L.	4	3.18	53	226	71	876
L. R. S.	4	5.99	64	331	55	844
E. R.	5	2.99	?	225	75	911
H. T.	5½	4.37	75?	420	45	797
L. O.	6	3.18	?	260	82	1008
E. N.	6	5.40	66	353	66	962
J. V.	8½	3.38	53	297	88	1108
T. C.	8½	4.72	66	353	76	1062
R. L.	8½	7.58	71	455	59	991

In every instance (and the number could be considerably extended) the infant with the smaller weight has the higher metabolism per unit of weight and also *per unit of surface.* There are two possible explanations: One, that the surface area as given for the smaller infant by the Meeh formula is too small and therefore the heat production is only apparently higher (Schlossmann, Frank and Wolff); and second, that the surface of the smaller infant as given by the formula is at least large enough (probably too large) and the metabolism is higher because the infant loses heat more rapidly. It need not be reiterated that the writer holds the latter view. At least it can scarcely be argued from this table that the lighter infant has the greater mass of active tissue. If this point is well taken we have an explanation which applies equally well to the results obtained by the direct and those obtained by the indirect methods of study.

The very low metabolism in the case of an eight-months child with congenital absence of cerebral hemispheres recently reported by Talbot[188] would seem to be in line with the explanation of the influence of body fat here adopted.

Influence of External Temperature.—There is no doubt that the rate of heat loss by radiation and conduction is affected by the external temperature. This is readily seen in the experiments of Richet, of Langlois and of Variot and Lavialle upon infants by the method of direct calorimetry. Richet made the first heat measurements ever recorded for infants and among his earliest observations were the following:

TABLE 38.—HEAT RADIATION FROM THE INFANT'S BODY AT DIFFERENT TEMPERATURES (RICHET)

Temperature, degrees Centigrade	Number of observations, averaged	Radiation calculated per kilogram and hour
18	2	4.532
19	3	4.484
20	2	4.218
21	1	3.762
22	4	4.090
23	1	3.135
24	2	2.689
25	1	2.622

Variot and Lavialle conducted most of their observations on normal and atrophic infants at 10°C.; but by way of contrast conducted a few at 20°C. The following may be selected from their tables by way of illustration. The infants selected were normal.

	CALORIES PER KILOGRAM AND HOUR
At 10°C.	3.1, 3.1, 3.3
At 20°C.	2.35, 2.0

Such differences as these do not signify of necessity that the child is producing more heat at the lower temperature, for, as noted on page 539, it is generally believed that cold alone independently of muscular motions does not increase the respiratory exchange in the adult. This has been confirmed for the infant by Schlossmann and Murschauser.[179] Careful record of every visible muscular movement of their subjects was made and it seems clear from the result that a difference of seven degrees at the range studied does not materially alter the metabolism. The greatest difference found is reproduced below:

Temperature, degrees	CO_2, grams		O_2, grams	
	Per kilogram and hour	Per square meter and hour	Per kilogram and hour	Per square meter and hour
16.9	0.950	12.12	0.800	10.21
23.4	0.928	11.73	0.773	9.77

In the two experiments here recorded the conditions as regards muscular activity were ideal in that the child slept throughout the periods of observation. In two other experiments on the same child there was nearly the same difference in metabolism, but the higher result occurred at the higher temperature. There is no question of the influence of food involved, for all of the experiments were conducted 18 hours after last feeding, only tea and saccharin being administered. One would like to be reassured, however, regarding the pharmacological action of thein and saccharin (p. 633).

If, then, the child radiates more heat at a lower temperature but does not oxidize more food (produce more heat), it follows that less heat must be lost by some other means; namely, evaporation of water. This function in the infant is known to be well developed even at birth[115] and is of equal importance with that of heat production in the regulation of body temperature. It seems to be the insensible perspiration[108] rather than perceptible sweat which is of greatest importance in keeping the body temperature from rising above the normal.

The Importance of Clothing in Heat Regulation of the Infant.—No treatment of the subject of metabolism of infants would be complete without at least a brief discussion of the influence of clothing. An attempt to visualize the influence of this factor upon the internal processes of energy metabolism is all that will be undertaken here.

Returning to the experiments by direct calorimetry, it may be noted that Variot and Lavialle observed very considerable differences in normal children by making what would appear at first sight to be rather trivial alterations in the clothing. The experiments were conducted at 10°C. Replacing a woolen diaper with a cotton cloth of the same dimensions increased the radiation 75 calories in 24 hours or enough to require the combustion of 100 gm. more of cow's milk. On the other hand, placing a single woolen cover over the child cut down the radiation 60 calories or 85 gm. of milk. The authors do not at this point sufficiently safeguard themselves against leaving the impression that this difference in metabolism actually occurs. It is obvious upon reflection that much of the heat saved from radiation by the woolen garment is removed by evaporation so that the total metabolism is not materially changed. The special virtue of wool as a clothing material is not so much that it prevents altogether loss of heat as that it retards loss of heat by radiation and facilitates its loss by slow evaporation. The experience of many an army officer in wearing woolen socks and woolen shirts in summer for the first time in his life is an illustration in point.

Variot and Lavialle exposed the limbs (legs and thighs) of some of their normal infants to the air at 10°C. and found in the case of one child 18 days old that an increased radiation and conduction of 160 calories, the amount contained in 225 gm. of cow's milk, resulted. Exposing the arms alone made a difference of 40 calories and covering the head reduced radiation and conduction 50 calories. Evidently an increased radiation in each case was accompanied by a reduced evaporation by reflex effect of cold upon the sweat glands or by vasoconstriction limiting the flow of blood to the surface, or both; for there is nothing in the literature of metabolism either of adults or of infants to warrant the supposition that exposing the legs or arms alone would increase the *heat production* in such proportions. The point is one which calls for early reinvestigation with a respiration calorimeter adjusted to different temperatures.

Helmholtz[73] and McClure and Sauer[108] a few years ago drew attention to the urgent necessity of attention to the factor of clothing for the infant in adaptation to higher temperatures. Experiments with puppies by the last named on the effects of a close-fitting cover of poorly conducting material (Canton flannel) sewed about the body proved that interference with heat loss in this manner is rapidly fatal when the external temperature (incubator) was brought to a level approaching that of the body itself. A considerable proportion of the deaths among infants in the early days of summer is believed by many to be due to this form of heat stasis and nothing else. From the standpoint of energy metabolism, the moral is that the processes of oxidation cannot be reduced below a certain basal level, if a full calorie diet is given, and still less if it contains a high protein ratio (p. 636); consequently there must be adequate means of removing the heat. It would seem that infants differ among themselves not a little as regards their capacity to regulate their body temperature whether by increased heat production (reaction to cold) or by increased heat loss (reaction to heat); and a practical physical means of determining the reaction capacity of the infant without subjecting him to untoward conditions would be a distinct advantage.

One other relationship recently emphasized by a study of thermal regulation in guinea pigs[65] is that at extreme temperatures the law of surface has only a relative value. At 35°C. the law no longer applies rigorously, apparently because of the inconstancy of the body temperature. In a warm environment like this the rectal temperature is higher the larger (fatter) the animal, while in the cold the rectal temperature falls with the weight of the animal. Large (fat) animals are therefore more sensitive to high temperatures while small (lean) animals are more sensitive to cold. This reinforces what has already been said regarding the rôle of body fat (p. 645). As applied to the child with its heat regulating mechanism imperfectly developed, these difficulties are certainly even more serious. Hence, the necessity of assistance, properly adapted to the amount of subcutaneous fat, through clothing.

In the experiments by Götsch on guinea pigs, just cited, it was noted that the production of CO_2 at 35°C. was 72 per cent. less than at 5.5°C.; and that the metabolism was progressively, though not proportionally, higher the lower the temperature. These observations are confirmatory of older observations by both Rubner[165] and Murschauser[131] on the same animal, and by Rubner on the dog. In none of these experiments were the muscular motions of the animals recorded, so that it must remain doubtful as regards these animals whether there is such a thing as a *pure effect* of temperature. All agree, however, in the observation that as the environing temperature is raised the metabolism ceases to fall at about 30°C., and from this point upward rises again. This is because the body temperature rises. This factor must now be considered briefly.

The Influence of Body Temperature.—A body temperature above normal in the absence of pathological processes is spoken of as a physiological fever. It may be most rapidly produced by surrounding an animal which has a limited capacity to perspire with an environing temperature near that of the body itself. The avenues of heat loss become, so to speak, clogged and the current of temperature production is dammed up in the organism. The animal responds by reducing its muscular motions to a minimum; it may stretch out on its back exposing the abdominal surface as much as possible in the familiar attitude of the tabby cat on a hot day; but if the external temperature continues to rise the basal metabolism is still too high and the body temperature rises. The processes of oxidation are thereby accelerated, more oxygen being consumed, more carbon dioxide produced and more heat generated. A vicious circle is established and a hyperthermia results from which the animal inevitably will die if the external conditions continue. In a toxic fever the avenues of heat loss are likewise inadequate. Recent studies on typhoid and malarial fevers by DuBois[8, 40] and his colleagues, using the respiration calorimeter, show that the organism is embarrassed in much the same way that an animal is in a physiological fever. While the body temperature is rising there is an increase in the metabolism. In malaria this occurs during the period of chill and may amount to as much as 100 to 200 per cent. of the normal rate. The heat loss remains near normal, hence is not adequate to keep up with the production and body temperature as a consequence rises. In the period of subjective warmth following the chill the avenues of heat loss are gradually opened up (perspiration) and the body temperature falls. Heat production long since has returned to normal. Contrary to the older conception that toxic fevers are due solely to interference with heat loss, we see that they are produced in much the same way that a physiological fever is produced, that is, by an acceleration of oxidation with the heat loss remaining low. Fevers in infants have not yet been studied by the indirect method. Some interesting observations by the direct method, however, have been recorded by French authors. Thus Langlois[49] taking as normal a heat "production" (measured by radiation only of the nude body at room temperature) for infants of 7 to 10 kg. body-weight, of 4.0 calories per kg. an hour, "which accords with the eighteen observations of Richet," finds the metabolism of chronically sick infants with subnormal temperature constantly below, and that of febrile cases constantly above this level. Two cases given on the next page are selected for illustration.

Bonniot [33] in a study of thermometry and calorimetry in infants ill with fever, presents some interesting curves of body temperature and heat elimination showing in every case, in accordance with the recent results in adults, that the point of maximum heat loss *follows* the point of maximum temperature. Respiration experiments on such cases it may be expected will show, in time, that the rise in temperature is due to increased oxidation *before* the means of heat loss have sufficiently reacted to meet the conditions. As already concluded from the statistical study of body temperature in relation to metabolism of the newborn (p. 609), the temperature is a consequence, not a cause, of the metabolism.

Case number	Disease	Body temperature	Heat radiation	Body weight	Ages
CI........	Tuberculosis	35.4°C.	2.990	5.00	2 years
CVIII.....	Broncho-pneumonia	38.7°C.	4.350	5.00	2 years

The Influence of Muscular Activity.—Here we have a factor in the total metabolism which becomes increasingly important the older the infant becomes; for not only does the basal metabolism increase with age (p. 639), but the mass of muscular tissue increases proportionally to the vegetative organs, and the continuous myelinization of motor pathways in the nervous system brings it more and more into action.

The first attempt to estimate the activity factor of the infant by the indirect method was a comparison on the 24-hour basis made by Rubner and Heubner[164] between the metabolism of their second breast-fed infant (1219 calories per square meter) and that of their first (1006 calories per square meter). The difference of 21 per cent. they ascribed entirely to this cause. Since the first infant was two and one-half months old while the second was five and a half, it is now assured that a part of the difference was due to age. Schlossmann and Murschauser[180] made the activity factor a special object of study in a comparison of the same infant while perfectly quiet and while crying hard. The child was two and one-half months old and weighed 2680 gm. They obtained these results:

Condition	Metabolism per square meter and hour		Increase	
	CO_2, grams	O_2, grams	CO_2, per cent.	O_2, per cent.
Quiet.....................	12.12	10.86		
Crying hard................	19.32	15.64	59.4	44

The extra metabolism in this case amounts to 1657 kg.-m. for one hour and assuming as the authors do that one-third of the extra metabolism may have taken the form of effective mechanical work, the infant would have preformed 550 kg.-m. of work which is the equivalent of one-fifteenth the amount done by an adult at hard labor. The estimate is certainly too high; for the most effective form of muscular work which a man can do, namely; lifting the body with the leg muscles, rarely exceeds one-third of the extra metabolism (p. 538). Working on a bicycle ergometer the muscular efficiency is only 21 to 28 per cent. It is not to be supposed that an infant in the act of crying can convert anything like this amount into effective work. A much higher ratio (than two-thirds) therefore doubtless takes the form of free heat.

Schlossmann[177] has made an estimate of the activity factor in another way. A child weighing 3500 gm. he estimates, on the basis of his and Murschauser's determinations, has a maintenance metabolism of 237 calories for 24 hours. Such a child consumes 500 gm. of breast milk with the following utilization:

	Protein, grams	N, grams	Fat, grams	Lactose, grams	Calories
500 gm. breast milk........	6.0	0.96	20.0	35.0	354.0
Retaining 30 gm...........	...	0.594	3.69		
Difference...............	...	0.366	16.31	....	50.0
Feces....................	...	0.100	0.31		
Metabolized.............	...	0.266	16.0	35.0	
Calories.................	...	7.1	149.0	143.5	299.6
Maintenance............	...	....	.....	.....	237.0
For muscular work (difference)	...	.....	....	.....	62.6

The 62.6 calories amounts to 26.5 per cent. of the maintenance metabolism. In another place Schlossmann[139] estimates that older infants with more active movements may use up an amount of energy equal to 30 to 40 per cent. of the maintenance metabolism.

Most of the observations reported upon the influence of muscular activity (crying) in infants are not uncomplicated by inequality in the influence of food. It cannot be overlooked that a child which is restless possibly from gas or an overfull stomach may at the same time be receiving a considerable dynamic stimulus from a high protein or high fat formula. The following citations seem to be entirely free from objections on this score. A normal child two months of age (Child 2, Table 26) was placed in the respiration incubator on each of two days which will be contrasted below, at the same interval after feeding. During the first hour on each day he slept perfectly throughout and the basal metabolism was the same. In the second hour of the second day, however, he slept one-third of the time (21 minutes) and cried quite actively and continuously for two-thirds (40 minutes). The metabolism was augmented as follows:

Condition	Calories per hour	Calories for 24 hours
Quiet	11.89	286
Crying two-thirds of time	17.45 = +44 per cent.	415 = +129 Calories

If it could be imagined that this child would sleep quietly one entire day and cry actively two-thirds of the time on the next his metabolism would be increased 44 per cent. or 129 calories, the equivalent of nearly 200 gm. of breast milk. The reason why a crying child "wants to nurse all the time" is obvious. The increase noted in this instance is the same as that observed by Schlossmann and Murschauser as regards the oxygen absorption of their infant of nearly the same age but very much lighter in weight; but is a little higher than was developed by Howland's underweight baby of seven months "while actively struggling and crying." The vigorous, lusty crying of a healthy, robust infant is naturally much more energy-consuming than the feeble, thin-voiced, though possibly just as "active" (relative to capacity) wailing of a sick infant.

A second infant three months of age (Child 4, Table 26) was fed exactly the same in amount and formula on two successive days, and was placed in the respiration apparatus at the same interval from feeding. In the second period of the first day he slept throughout making only three readjustment movements (p. 629) in the hour. In the second period of the second day the child "fretted and cried" one-third (20 minutes) of the period and slept quietly the other two-thirds (40 minutes). The metabolism was as follows:

Condition	Calories per hour	Calories per 24 hours
Sleeping entire hour	10.75	258
Fretting and crying 20 minutes Sleeping quietly 40 minutes	12.04 = +12 per cent.	289 = +31 Calories

The restlessness of this child was probably not greater than is normal for any healthy infant.

The practical interest in the influence of crying is not how much an infant can increase his energy exchange by a few moments of paroxysmal rage but how much energy a child may actually use up in the course of 24 hours. Some figures which have been published on this subject are, from this point of view, mere curiosities of metabolism, and being based upon the CO_2 output, it is feared they are not even trustworthy. As already noted on page 607 in connection with the metabolism of the newborn the heat production based upon the CO_2 elimination, especially if preliminary periods in which it is impossible to secure the respiratory quotient even approximately by averaging it with other periods, are included in the reckoning, may produce rather large errors (p. 587).

Not only is the CO_2 in the crying period too high, but in a subsequent period of deep sleep it is too low for reasons which have already been explained. A recent estimate of the activity factor[189] based upon a nearly continuous record of the CO_2 ouptut for the 24 hours disclosed a difference between maximal and minimal periods of 67 per cent. for an infant two months and three weeks of age and 70 per cent. for one six months and one week old. These percentage differences would not have been so high if preliminary periods had not been included.

Taking high and low periods together and estimating at a maximum the metabolism for the intervening time in which the child was nursing and being redressed, as Talbot has done, gives the really important result; namely, the total energy expenditure for the 24 hours. This reveals a metabolism per unit of surface very close to that found by Rubner and Heubner for their first breast-fed infant by the all-day method (Table 25). It is gratifying to find the earliest and latest results in agreement as regards the total expenditure of energy for the normal life of a healthy breast-fed infant. The slight differences which remain are well within the range of variability for activity, age, etc.

TABLE 39.—TOTAL ENERGY EXPENDITURE OF TWO NORMAL INFANTS FOR 24 HOURS (TALBOT)

Child	Period	Carbon dioxide, grams	R. Q.	Heat computed, 24 hours		
				Total	Per kilogram	Per square meter (Meeh)
E. L.	Measured 22 hr. 31 min.	120.8	0.87	345		
2 mo. 3 wks.	Estimated 1 hr. 20 min.	9.3	....	27		
	Total	130.0	....	372	74	1066
E. L.	Measured 23 hr. 10 min.	130.4	0.83	387		
6 mo. 1 wk.	Estimated 50 min.	5.6	....	17		
	Total	136.0	....	404	70	1059

The Total Energy Requirement of Infants from Two Weeks to One Year of Age.—The requirements of energy in the form of milk, or milk with additions, for the normal infant may now be estimated with a fair degree of accuracy. To the total energy production as revealed in measurements by the indirect method (see previous sections) must be added an allowance for non-absorption and a quota for growth; or to the minimal metabolism of the infant recently fed and sleeping may be added first an allowance for activity and then the other quotas. Murlin and Hoobler and Talbot agree in finding for this basal in the neighborhood of 60 calories per kilogram and hour. They also agree that for the infant that cries very much and very hard 40 per cent. additional will cover the actual expenditure of energy. For the average infant sleeping an average length of time the quota for activity should not be more than 15 per cent.

Rubner and Heubner[162] give for their first breast-fed infant nine weeks old and weighing 5235 gm. the following balance of energy.

TABLE 40.—ENERGY BALANCE OF AN INFANT NINE WEEKS OLD (RUBNER AND HEUBNER)

Nutrients	Utilized in 24 hours	Heat value, grams	Calories in 24 hours
N-containing material	5.56	5.899	32.76
Lactose	43.02	3.951	169.97
Milk fat	16.7	9.247	154.42
Body fat	2.4	9.500	22.80
Total	....	.....	379.95

Lost in Excreta

Substance	Dry weight	Heat value, grams	Calories in 24 hours
Urine	2.51	2.930	7.35
Feces	3.79	5.730	21.72
Total	....	.....	29.07

Net heat production, 379.95 − 29.07 = 349.86

The physiological net effect (utilization) of mother's milk in this child was 91.6 per cent., leaving a loss of 8.4 per cent., 2.6 per cent. of which was through the urine and 5.8 per cent. through the feces. In their second breast-fed infant five and one-half months of age and weighing 9600 gm. the net utilization was 94 per cent. Holt, Courtney and Fales[80] found an average utilization of 95.1 per cent. of the intake of fat for eight healthy breast-fed infants from 3 to 10 months of age. The range of utilization was from 90.3 to 99.2 per cent. An allowance of 10 per cent. for non-absorption and loss by intestinal secretions (p. 744) in the case of breast-fed infants therefore would seem to be an abundance.

For an artificially fed infant of seven and one-half months and weighing 2635 gm. Rubner and Heubner[163] observed after a diet of whole milk plus 3 per cent. milk sugar a net utilization of 90.7 per cent. Schlossmann,[173] using the Hempel calorimeter for determination of the heat value of the feces, emphasized the fact that rarely more than 10 per cent. of the energy value of the food was found in the stool. Holt[78] and his collaborators found an average of 12.4 per cent. of the food fat in normal stools of healthy, bottle-fed infants, and since the percentile energy loss from all the food stuffs is never so high as that from fat alone, Talbot's[189] estimate of the loss by the stools as 15 per cent. *of the basal metabolism* may be accepted as very liberal.

It is customary to calculate the loss of energy in the form of nitrogenous bodies in the feces, from the total nitrogen, multiplying by the average factor for food proteins and by the average heat value of proteins. It is well konwn, however, that the major portion of these nitrogenous bodies are not derived from food which has escaped digestion but represents rather the residues of the digestive juices and the live or dead bodies of bacteria. For this reason many authors[43] do not consider it worth while to make an estimate of the net utilization in percentage of intake. It would seem to be equally fallacious to estimate the energy loss on the assumption that the total nitrogen of the feces represents protein of an equal value with the food protein. Van Slyke[195] has found in fact, that, of the total nitrogen present in infants' stools, 50 to 70 per cent. occurs in the form of protein or proteolytic products, 2 to 24 per cent. being present as free amino-acids and 3 to 37 per cent. as ammonia, the latter fraction being derived for the most part certainly by bacterial action upon the proteins or their cleavage products. Use of the bomb calorimeter in estimating the energy loss through the feces is therefore to be preferred.

Growth in its Relation to Energy.—While metabolism is certainly more active in the youthful organism than in the adult it is by no means proved that growth *per se* calls for any expenditure of energy. In recent times the view seems in fact to have gained rather general acceptance that the larger metabolism of the young is necessary in the interest of heat regulation. At the same time the propensity to grow, which is the certain sign of youth in health, may be given a sort of energy index. There is a considerable body of evidence[105] that growth in a given genus is proportional to the potential energy of the food consumed, and the proportion of gain in weight to energy intake may be quite similar in different genera.* It would seem that the growth impulse which, in some way not at all understood, directs and governs developmental events through the processes of nutrition, is geared, so to speak, at a very similar speed in relation to energy intake in several genera and orders of mammals. A kilogram of body substance in several of them contains, according to Rubner,[161] 30 gm. N and 1722 calories of potential energy. To produce this unit of growth requires in the earliest period of post-natal development approximately the same amount of food energy; namely, 4088 calories. The human infant, however, occupies an exceptional position, in this regard, which may be expressed as follows: Of 100 calories of energy in the form of milk there is utilized for growth in the

	PER CENT.
Colt	33.3
Calf	33.1
Lamb	38.2
Pig	40.2
Puppy dog	34.9
Kitten	33.0
Young rabbit	37.7
Average	34.3
Human infant	5.2

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* This statement in view of recent developments in the realm of the chemically unknown accessory substances (vitamines) must be guarded by the saving *proviso* that an adequacy of these several substances is assumed.

The average ingestion of milk in relation to the maintenance requirement (this term in Rubner's usage is not synonymous with basal metabolism) in the mammal is 202 per cent., while for the infant it is only 120 per cent.

The relatively long infancy period in the human family, it would seem, is a consequence rather than a cause of this difference; for if the large amount of time spent in sleep explained the low intake of food, and the slow development were a consequence of this, then keeping the baby awake and thereby increasing the demand for food ought to accelerate its growth. Of course just the opposite is true. Owing to a growth impulse of low speed, which in turn probably determines capacity for food (anatomical capacity of the stomach and functional capacity of metabolism) on the part of the infant, the human mother is called upon to supply intelligent care and protection rather than bulk of nutrients. Interesting biological implications are involved which space does not permit us to develop at this time.

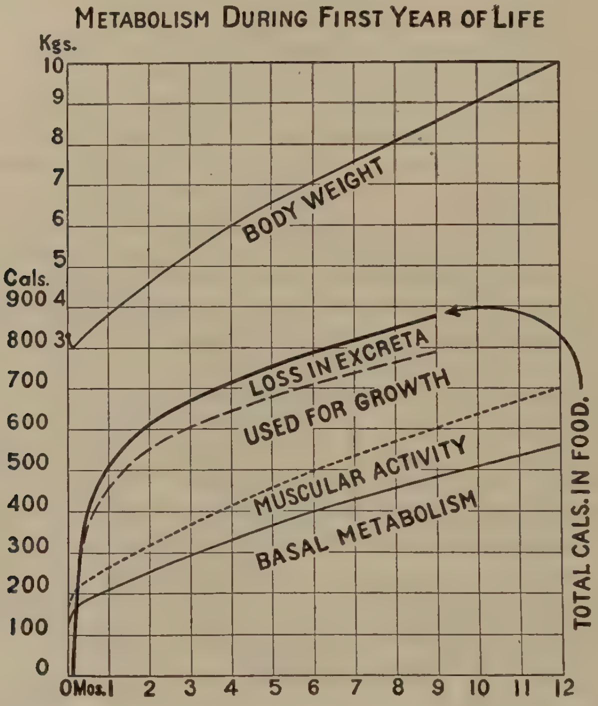

FIG. 222.—Chart showing metabolism during first year of life. (Talbot, Amer. Journ. Dis. of Children, 1919, xviii, Chart 2, p. 231.)

It is doubtful whether the growth quota of energy, *i.e.*, the portion left over after the maintenance factor, the activity factor, the dynamic factor and the loss by non-absorption have been covered, can ever be fixed as a definite percentage of the maintenance metabolism for all varieties of infants. The growth impulse, as between individuals, quite as truly as between different orders of animals, is more a matter of heredity than of food. Moreover it is inherited from the father equally with the mother, so that a small mother nursing the child of a large father may not be able to supply milk enough for the rate of growth which the child has inherited. Again it is well known that

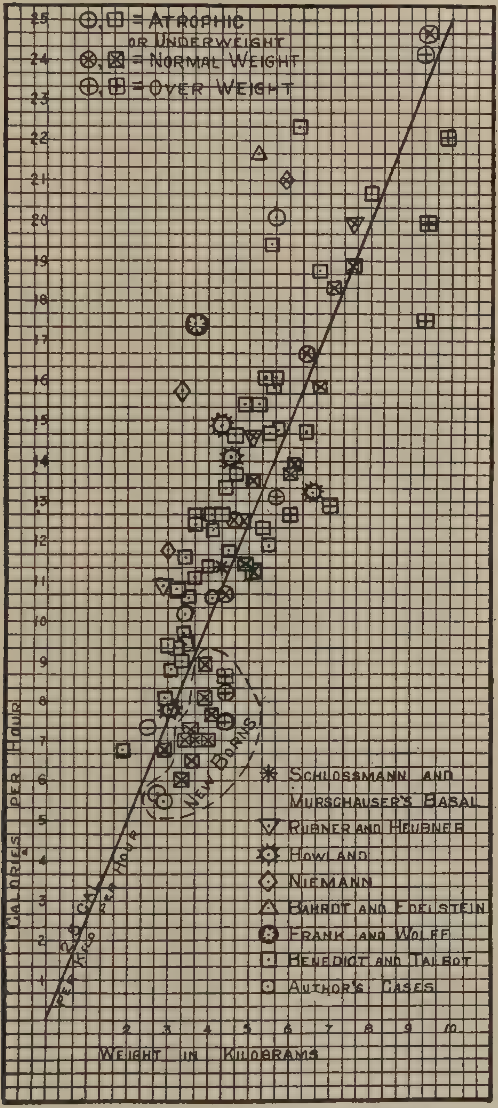

Fig. 223.—Diagram showing relation of heat production to body weight of infants from birth to one year of age. (Murlin and Hoobler, Amer. Journ. Dis. of children, 1915, ix, Fig. 9, p. 113.)

growth in height often will proceed at a time when nutrition is not sufficient to support growth in weight, and both vary with the season of the year.[29] In time we shall have, in addition to statistical criteria,

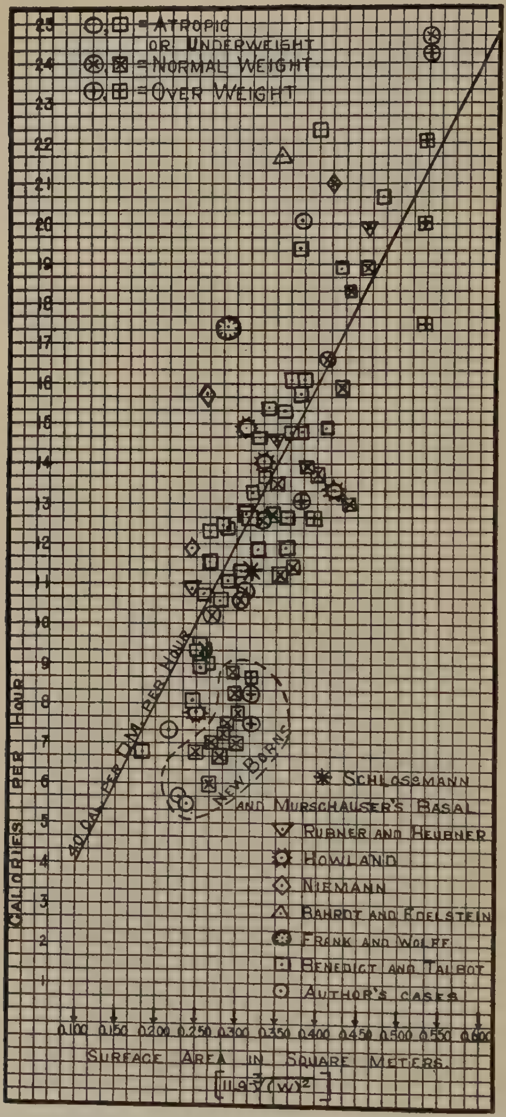

FIG. 224.—Diagram showing relation of heat production to surface area (Meeh) of of infants from birth to one year of age. (Murlin and Hoobler, Amer. Journ. Dis. of Children, 1915, ix, Fig. 10, p. 115.)

physiological norms of growth which will simplify the whole problem of infant feeding. At present it is impossible to formulate even a satisfactory physiological definition of the growth rate. Merely to emphasize the multiplicity of factors contending for energy before growth can be wholly satisfied, and to visualize what is known of their quantitative relations, the following tabular arrangement may be presented:

Basal metabolism		60 calories per kg.
Activity metabolism (12 to 40 per cent. of basal)	7.2 to	24.0 cal. per kg.
Loss by feces (10 to 15 per cent. basal)	6.0 to	9.0 cal. per kg.
Dynamic action (10 to 20 per cent. basal)	6.0 to	12.0 cal. per kg.
Growth (10 to 20 per cent. basal)	6.0 to	12.0 cal. per kg.
Total	85.0 to	120.0 cal. per kg.

This estimate is liberal in all divisions of the caloric needs. Careful reckoning of the fate of the food energy cannot account for more than is here allowed except in such extreme restlessness as would place the case clearly in the pathological field.

This classification is not to be looked upon as anything fixed. As shown by the charts (Figs. 223, 224) the basal requirement increases steadily up to one year of age or later. The requirement for activity increases steadily in the absolute sense as the child spends more and more time awake, but it is not yet certain whether the increase is also relative to basal needs on the basis of weight or surface. Utilization is not known to change with age, the results with very young infants being often quite as favorable as with older ones. Dynamic action has not been sufficiently studied to say definitely whether it is greater or less as more and more food is ingested at a meal. There are indications that it is greater. Finally, the requirement for growth relative to weight increases certainly for the first three months and possibly up to six months, after which it flattens out (Fig. 222). We have yet to learn whether the growth increment (in calories) advances more or less rapidly than the basal requirement. Von Pirquet,[141] who has recently invented a system of computing food requirements, obviously based upon energy units (and merely disguised as "nems") estimates the growth quota at one-third the minimal or maintenance requirement. What this estimate is based upon is not disclosed by any of the reviews available to the writer. From the observations of Soxhlet on the calf it has been estimated[160] that this animal can utilize over 40 per cent. of the food energy for growth, but an infant of seven months[163] was able at best to so dispose of only 13 per cent. Mere fattening should not of course be included as growth.

Energy Quotient.—Following Heubner[75] the total requirement of the normal infant in order to make a satisfactory rate of growth and development, and covering all the several needs outlined above when expressed as calories per kilogram of body weight, has been known as the "energy quotient." Heubner himself gave the following estimate.

100 calories per kilogram for first three months.
90 calories per kilogram for second three months.
80 calories per kilogram thereafter to end of nursing.

Numerous different estimates have been given by clinicians;[58] but they need not be gone into here, for it is evident from the discussion which has preceded that it is impossible at this time to give even a satisfactory average requirement for different ages, or weights, or heights, much less one which will suit the individual needs. Much careful work must be done before even this modest ambition can be realized; and then it would be necessary to institutionalize the care of children far beyond our present ideals. Variations in the composition of milk, particularly breast milk, with regard to inorganic as well as organic constituents must be taken into account; and the whole question will probably have to be restudied in the light of what is already known of vitamines. Assuredly the minimal energy requirement for satisfactory growth cannot be defined without the certainty that all the vitamines are present in effective quantities.

Energy Metabolism of Children from Nursing Age to Puberty

Introduction.—The reason for separating children of this age group from the nursing age is again a practical one. The processes of metabolism are continuous but nutritional problems on account of the change to more and more solid foods are different. Questions of selection, of adaptability, of capriciousness and idiosyncrasy more often arise; while the muscular activity of the child has now become so great as to present peculiar problems to the investigator whether of basal metabolism, of muscular efficiency or of the total daily needs. The dynamic action of foods because of longer intervals between meals is quite different on a mixed diet than upon milk, and the criterion of growth shifts from a weight-for-age relationship to a weight-for-height ratio. All these seem to the writer adequate reasons for discussing the energy metabolism, which must always remain an indispensable quantitative guide to proper food selection of children above nursing age, in a section by itself.

Methods of Study.—Little need be said under this heading different from what has already been emphasized in the previous section. Instrumentally the methods are in the main the same except for capacity. A larger chamber must be used and for the indirect methods of measurement absorbers of respiratory products must be larger or more numerous. With children old enough to control the sphincters the collection of urine and feces is simplified and the nitrogen factor in energy metabolism can be used if considered necessary. The face mask or mouth piece can be used in lieu of a respiration chamber and important results obtained at less expense for equipment. The coöperation of the subject can be secured through the love of prizes or of sweets and in the older children through the feeling of pride and the desire to please.

Basal Metabolism.—Logically, as we now see very clearly, everything starts from the minimal or mere maintenance requirement, although historically the order has been quite different. The latest and in many respects the most complete researches have been made upon the basal metabolism. It is proper, however, to see how much has been learned regarding basal needs from earlier investigations.

The Zuntz school headed by the late N. Zuntz of Berlin had long emphasized the necessity of eliminating the influence of muscular activity and of food if results upon subjects of different size or age were to be compared. Magnus-Levy and Falk[109] followers of Zuntz, employing the well-known method of Zuntz and Geppert with which important results had been obtained on the influence of muscular work in mountain climbing, in marching, and in the treadmill, on the influence of altitude and on the influence of digestion, undertook in 1899 an investigation on the influence of age on the basal metabolism. The subjects ranged from two and one half years to old age. Included in these were 11 boys and nine girls under 14 years of age. At the time of observation the subjects were all in the *nüchtern* condition, which is Zuntz's term for the absence of digestion, *i.e.*, at least 12 hours since taking food, or, what has been called by others, the "post-absorptive state." The subject lay upon a couch and suppressed all muscular contractions. The Zuntz method, as described on page 534, permits of the determination of oxygen absorbed as well as of CO_2 eliminated.

The results upon the group of children mentioned above are presented in Table 35.

TABLE 41.—THE GASEOUS EXCHANGE OF CHILDREN* (MAGNUS-LEVY AND FALK)

Age, years	Weight, kilograms	Height, centimeters	O_2 consumed		CO_2 eliminated		R. Q.	Calories per square meter and hour
			Per kilogram and hour, cubic centimeters	Per square meter and hour (Meeh), liters	Per kilogram and hour, cubic centimeters	Per square meter and hour, liters		
2½	11.5	?	585	10.74	488	9.01	0.83	51.9
6	14.5	110.0	552	10.92	442	8.83	0.80	52.4
6	18.4	110.0	457	9.78	366	7.87	0.80	46.9
7	19.2	112.0	476	10.32	402	8.89	0.85	50.2
7	20.8	110.0	478	10.68	397	8.83	0.83	51.6
9	21.8	115.0	407	9.24	346	7.80	0.85	44.9
11	26.5	129.0	374	8.22	300	7.33	0.80	39.4
10	30.6	131.0	377	8.52	315	7.98	0.84	41.3
14	36.1	142.0	313	8.40	264	7.03	0.84	40.7
14	36.8	141.5	301	8.10	254	6.84	0.84	39.3
14	43.0	149.0	308	8.76	249	7.14	0.81	42.1
Girls								
7	15.3	107.0	490	9.90	397	7.99	0.81	47.6
6½	18.2	?	445	9.48	361	7.74	0.81	45.6
12	24.0	129.0	338	7.92	310	7.27	0.92	39.2
12	25.2	128.0	322	7.68	264	6.30	0.84	37.2
13	31.0	138.0	332	8.46	259	7.58	0.89	41.6
14	35.5	143.0	317	8.46	259	6.95	0.82	40.8
12	40.2	?	295	8.22	229	6.43	0.78	39.2
11	42.0	14.9	301	8.52	244	6.84	0.81	41.0

* This table is reconstructed in part from a table given by Tigerstedt in Nagel's Handbuch der Physiologie 1909, I, p. 475, and in part from a table in Magnus-Levy's Physiology of Metabolism.[110]

The respiratory quotient characteristic of the *nüchtern* condition in children is well illustrated in this table. The average is 0.82 for boys and 0.84 for girls. With adults the quotient is quite commonly several points higher for the reason that adults do not consume their store of glycogen quite so rapidly. This is in accord with the well-known fact that fasting is much more exhausting for children than for adults. The capacity to handle carbohydrates in the diet is the basis of the craving for sweets among children.

The arrangement in Table 41, following that of the authors themselves, is according to weight rather than age. It is apparent at once that the metabolism in both sex groups decreases as age and weight increase, whether it is estimated on the basis of a unit of weight or a unit of surface. This has been confirmed, as we shall see presently, when a very different method of measuring surface is employed. The authors compared the oxygen absorption of these children with adults of the same sex under the same conditions of observations. Referred to a unit of weight the metabolsim of children from two to fourteen years of age was found to be from 1.3 to 2.8 times that of the adult. Referred to a square meter of body surface it was 1.2 to 1.6 times as great. Contrary to the belief of the Rubner school up to this time this research demonstrated clearly that the metabolism on the basis of body surface is by no means uniform for all ages. Comparing the basal metabolism of a boy and a girl, on the basis of the oxygen absorption, with adults of middle age, and of old age having approximately the same body-weight the following result was obtained.[110]

TABLE 42.—GASEOUS EXCHANGE AT DIFFERENT AGES (MAGNUS-LEVY AND FALK)

	Age	Weight, kilograms	Height, centimeters	Absolute amounts of		Relative amounts of	
				O_2 c.c. per min.	O_2 c.c. per kilogram	O_2 per kilogram	O_2 per square meter surface
Girl	13	31.0	138	171.7	5.54	112	111
Woman	49	31.6	134	156.6	4.96	100	100
Old woman	75	30.3 circa	140(?)	128.6	4.25	86	84
Boy	15	43.7	152	216.6	4.97	110	100
Man	24	43.2	148	195.8	4.53	100	100
Old man	71	47.8	164	163.2	3.42	75	78

They concluded that children produce more heat not merely for the reason that their superficial area is greater in relation to their weight but more also on account of the increased vital energy characteristic of youth.

Sondén and Tigerstedt[187] in the course of an extensive investigation on the metabolism of children sitting quietly as in school, which will be presented later, obtained results on two boys 11.2 and 12 years of age respectively while sleeping. They found the CO_2 elimination on the basis of surface area (Meeh) 52 per cent. higher than that of adults in sleep. While the conditions of these experiments did not exclude the influence of food altogether, they approached the true basal conditions very closely and furnished early evidence of a variation directly caused by a difference in age. The conclusion of these authors agrees with that of Magnus-Levy and Falk that the youthful body in and of itself independently of its small size possesses a more active metabolism. The higher metabolism of children on the basis of weight had been demonstrated long before this by Scharling [169] and by Forster.[56] The last-named summarized the observations of Scharling as follows:

CHILDREN	
Boys, 8 to 14 years	0.29 gm. CO_2 per kilogram.
Girls, 8 to 14 years	0.26 gm. CO_2 per kilogram.
ADULTS	
Men 26 to 58 years	0.14 gm. CO_2 per kilogram.
Women, 15 to 25 years	0.15 gm. CO_2 per kilogram.

The unit of time is not stated. The observations were made by means of a respiration chamber which has recently been described by Benedict and Carpenter.[16] Forster gave his own results upon children in the following summary based upon a unit of 10 kg. of body weight.

Boys and girls, 3 to 5 years of age	9.0 gm. CO_2 per hour.
Boys and girls, 6 to 7 years of age	11.7 gm. CO_2 per hour.
Boys and girls, 9 to 13 years of age	8.0 gm. CO_2 per hour.

And compared them with results obtained by Pettenkofer and Voit on adult men upon the same unit of weight:

Men—fasting and resting	4.4 gm. CO_2 per hour.
fasting and working	7.1 gm. CO_2 per hour.
Moderate diet and working	7.2 gm. CO_2 per hour.

The conclusion was that children up to thirteen years of age gave out more CO_2 even when resting than do adults while at work. The children had received only a light meal of bread and milk the evening before and were placed in the respiration chamber one and one-half to two hours after a very light breakfast.

To continue the subject of basal metabolism of children we may proceed at once to the very recent observations of Benedict and Talbot[24] advance proofs of whose monograph have very kindly been sent to the writer by the senior author. This research is a continuation of the studies on basal metabolism in infants which has been referred to extensively in preceding sections. The work on children up to two years of age was done at the Directory for Wet Nurses of the Boston Infant's Hospital and on children from two years to fifteen years of age at the New England Home for Little Wanderers.

As might be expected from their previous publications the authors lay great stress upon the fulfillment of really basal conditions, although they found it necessary especially in younger children, partly on account of the danger of a complicating effect of acidosis in fasting[181] and partly because children cannot be kept quiet on empty stomach, to tolerate at times the influence of food. This was offset in some cases by the reducing effect of sleep after taking food. The coöperation of the child was secured by a system of prizes and a sufficient number of experimental periods were obtained to secure in many instances at least a true basal or minimal metabolism. An outstanding feature of the research is the consecutive observation of a number of children at varying intervals for periods of several months to as much as four years. The apparatus used for children up to two years of age is shown in Fig. 225. The technique of operation has already been given fully at page 560. The apparatus for larger children differs from this only in the size of the chamber used, which was a small clinical respiration chamber like that described by Benedict and Tompkins.[25] The normality of their subjects (Fig. 226) was established not only by exclusion of all children exhibiting any clinical symptoms, but by comparison with the series of normal American children weighed and measured by Crum and Wood, as assembled by Gray,[67] with the private school children of Holt[77] and with a new series of private school children weighed and measured by the authors themselves, in addition to the older series of foreign children studied for physical development by Quetelet[142] and Schmid-Monnard.[182]

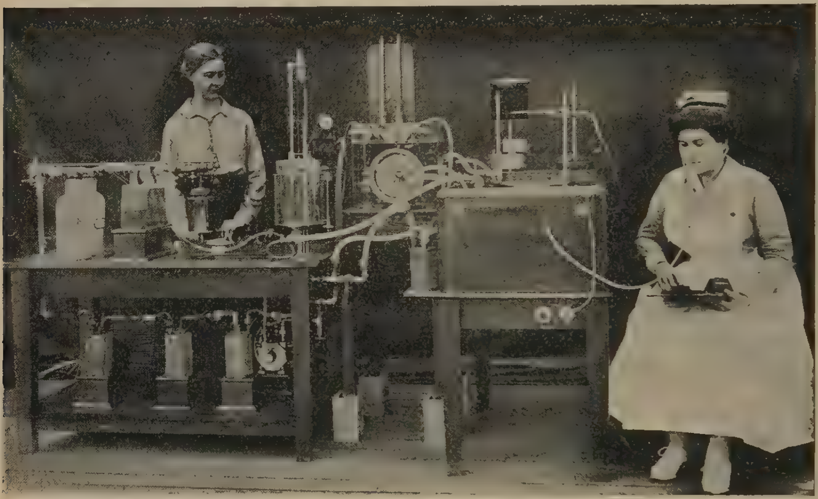

Fig. 225.—Infant respiration apparatus as used at the Directory for Wet nurses in Boston. At the right are the respiration chamber, the tambour, and kymograph for recording the muscular activity, also nurse counting pulse-rate. At the left is the absorbing system, with the carbon dioxide absorbers and spirometer on the upper shelf of the table, the water-absorbers and blower on the lower shelf. The gas meter for measuring the oxygen may be seen in the center. (Benedict and Talbot.)

Two charts containing curves showing the relation of weight to height of the boys and girls studied by Benedict and Talbot in com-

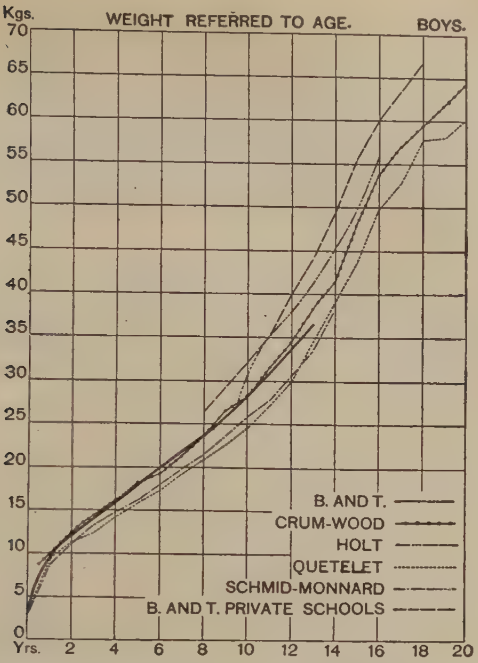

FIG. 226.—Chart showing relation of Benedict and Talbot series of boys to to other standard series, on the basis of weight referred to age. (Benedict and Talbot, Carn. Inst. of Wash. Publ. No. 302, 1921, Fig. 3, p. 40.)

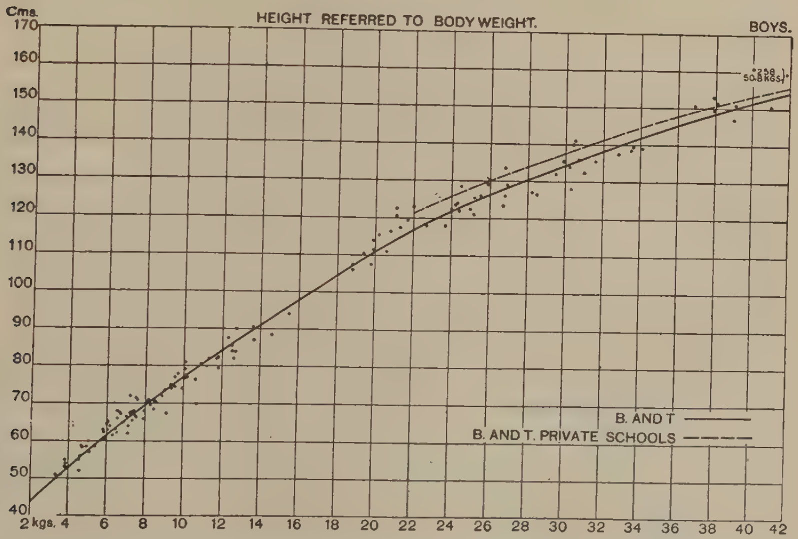

FIG. 227.—Chart showing difference between Benedict and Talbot experimental series of boys and boys of private schools near Boston. (Benedict and Talbot, Carn. Inst. of Wash. Publ. No. 302, 1921, Fig. 7, p. 45.)

parison with similar curves for children in private schools near Boston are given in Figs. 227, 228. A discussion of the factors influencing growth is out of place in this chapter, but attention may be directed to the interesting fact brought out in these curves that private school children, which are supposed to represent the physical aristocracy of childhood in America, are lighter for height than the mediocrity represented by the children of wet nurses and orphans which make up the observational series.

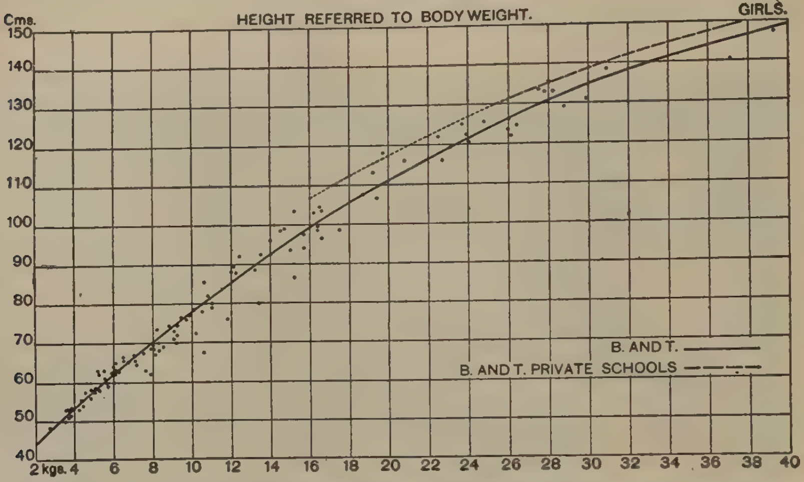

FIG. 228.—Chart showing difference between Benedict and Talbot experimental series of girls and girls of private schools near Boston. (Benedict and Talbot, Carn. Inst. of Wash. Publ. #302, 1921, Fig. 8, p. 46.)

Influence of Age on Basal Metabolism of Children.—Among the subjects studied at intervals over a long period of time by Benedict and Talbot was a girl, designated in their series as No. 145, whose record extends from the age of five months to the age of three years and five months. In all she was placed in the respiration chamber on 31 different days and the observational periods of approximately 30 minutes each numbered four to five daily. The minimal metabolism is given for 25 different days and the accompanying chart represents 19 distinct points in the course of the three years (Fig. 229).

The most rapid growth as would be expected is seen in the first half of the time, namely, from the fifth to the twenty-first month. During this time the basal metabolism, calculated to 24 hours (called "total calories" in the chart), rises nearly parallel with the growth in weight, after which the metabolism rises less rapidly than the weight. It is evident from the curve representing metabolism per unit of weight, however, that the parallelism is only apparent and arises from the fact that metabolism and weight are plotted to ordinates which are not strictly proportional; for the metabolism per kilogram falls from the beginning instead of running horizontally. The level at five months is 60 calories per kilogram and at 24 months it has dropped to 38 calories. From this point onward the curve is horizontal indicating that the progress in growth is equal to the progress in basal heat production. Charted on the basis of a unit of body surface (DuBois linear formula) the general trend again is downward—from 1,086 calories at five months to 841 at 24 months from which time it rises to nearly 900 calories per square meter at 41 months.

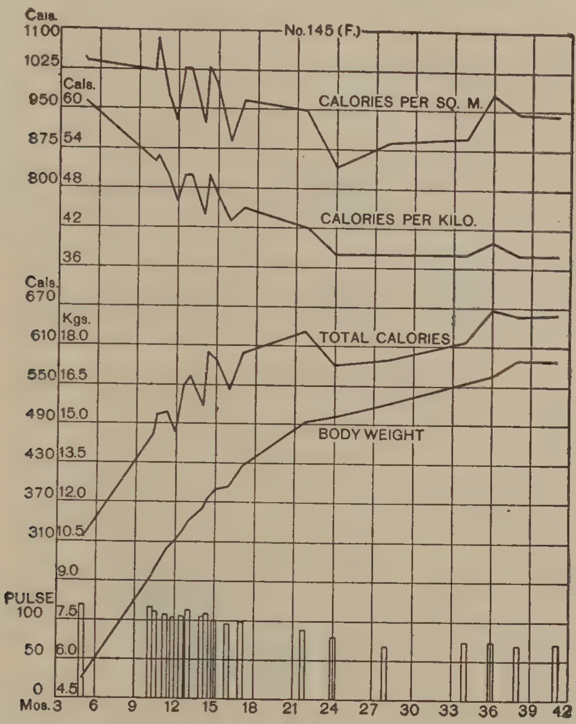

FIG. 229.—Basal metabolism on the basis of 24 hours of normal infant No. 145, at different ages. (Benedict and Talbot, Carn. Inst. of Wash. Publ. No. 302, 1921, Fig. 15, p. 114.)

Numerous other individual records for shorter periods of time are given, with approximately the same general results. Figure 230 gives the progress of the basal metabolism in relation to weight for boys for the entire series of children studied in comparison with the scattered observations of other investigators. In the first of these charts it may be seen that the basal metabolism in boys as determined by the most recent observations runs from a little less than 100 calories daily at 2 kg. body-weight to 1,325 calories at 42 kg., or from about 45 to about 31 calories per kilogram. With girls the curve starts at a slightly lower level, at 2 kg. and rises to 1,100 calories daily, at 32 kg.; or from about 40 to about 34 calories per kilogram. The values obtained by

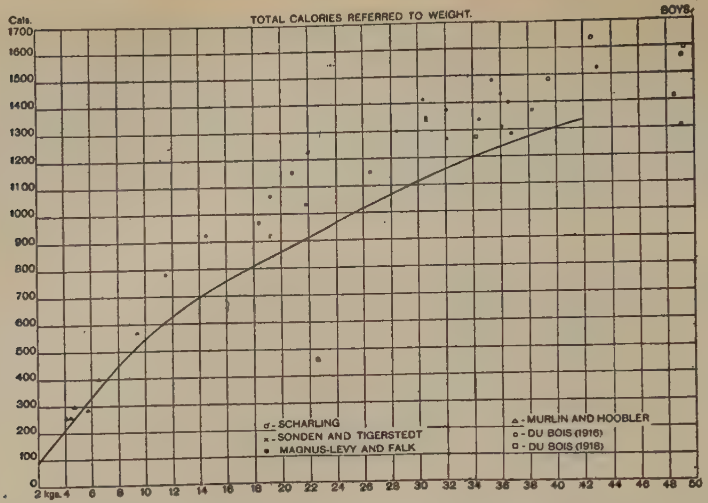

FIG. 230.—Chart showing progress of basal metabolism on basis of weight for boys from birth to puberty as compared with observations of others. (Benedict and Talbot, Carn. Inst. of Wash. Publ. No. 302, 1921, Fig. 28, p. 143.)

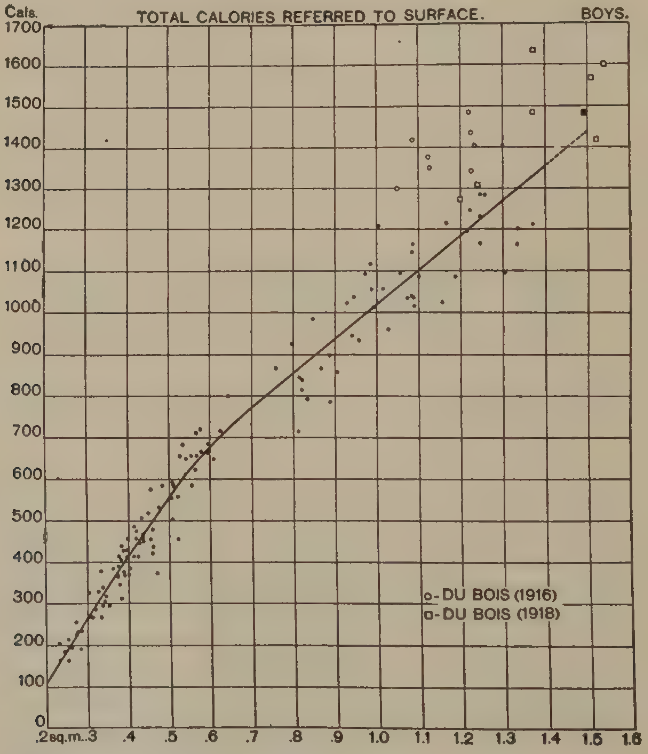

FIG. 231.—Chart showing progress of basal metabolism on basis of body surface (DuBois linear formula) as compared with the DuBois series of boys before and after puberty. (Benedict and Talbot, Carn. Inst. of Wash. Publ. No. 302, 1921, Fig. 38, p. 161.)

Benedict and Talbot are lower than those obtained by any previous observers except Olin.* Curves of the same general character are obtained when the total basal heat production calculated to 24 hours is referred to the body surface (Fig. 231). The surface area in these observations was calculated from numerous actual measurements according to the DuBois linear formula, and a revision of the formula of Lissauer is proposed by derivation of the constant, with which the two-thirds power of the weight should be affected, from the surface as measured. The authors find a slightly closer agreement upon this basis than upon the basis of weight, but persist in their belief that there is no causal relationship between body surface and heat production. Apparently this belief emanates from the discovery that heat production is no more, or at most only slightly more, closely related to body surface as among different children than to body-weight. This discovery, as pointed out on page 642, could have been made with pencil and paper so far as subjects are concerned whose weights differ only a little. A change in formula from Meeh to Lissauer or to the DuBois linear formula, which, it seems can be expressed by Lissauer's formula with a somewhat variable "constant," makes no difference in the reasoning. Moreover, a correlation study of this series of children doubtless would show what such a study upon newborns has

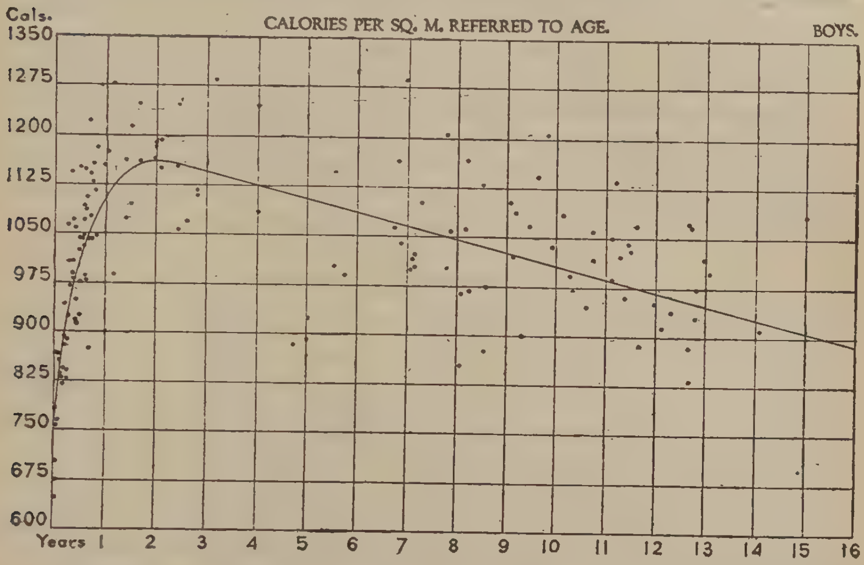

FIG. 232.—Chart showing basal metabolism on basis of body surface (DuBois linear formula) referred to age, of boys from birth to puberty. (Benedict and Talbot, Carn. Inst. of Wash. Publ. No. 302, 1921, Fig. 45, p. 174.)

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*Sufficiently detailed information is not given to render possible an independent judgment whether this minimal metabolism is not in fact somewhat too low for reasons which were discussed at page 586.

shown; namely, that the choice of formula affects but slightly the degree of correlation between heat production and body surface (p. 600). The vastly better agreement between basal heat production and body surface than between this physiological character and body-weight, as between individuals of the same species but of widely different size, remains as a challenge to disbelievers. The factor of age must be taken into account as now is definitely established by the work of the several authors described above. The most recent work confirms very nicely, so far as it goes, the age curve of DuBois given on page 548, except that the newer results are somewhat lower (Fig. 232). The average metabolism per square meter of surface (whatever formula is used), like the metabolism per kilogram., is low for the early months of life, rises rapidly toward the end of the first year, reaches its maximum at some point in the second year and then falls much more slowly than it rose, continuing to fall to the age of prepubescence.

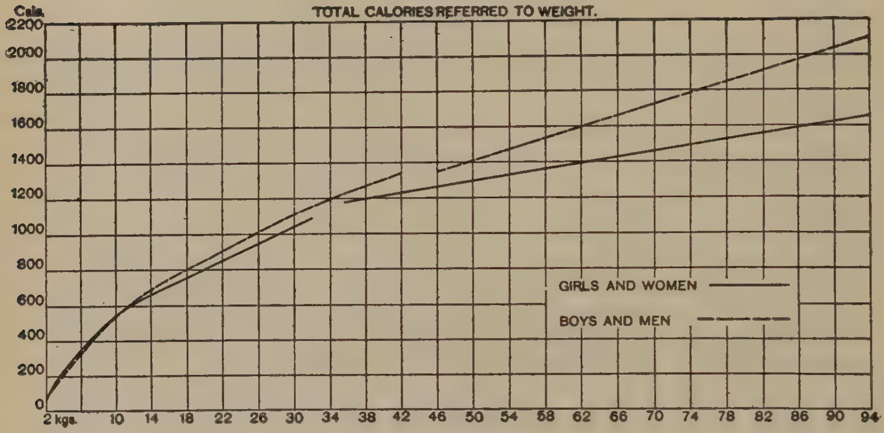

FIG. 233.—Chart showing basal metabolism of boys and men compared with that of girls and women, on basis of weight. (Benedict and Talbot, Carn. Inst. of Wash. Publ. No. 302, 1921, Fig. 48, p. 179.)

Benedict and Talbot find wide variations from their mean curves—from 29 to 64 calories per kilogram and 24 hours for boys and an even wider range for girls; from 650 to 1,275 calories per square meter (DuBois linear formula and Lissauer formula modified) per 24 hours for boys, and from 600 to 1,350 for girls. The widest variation on both bases for any single age falls in the latter half of the first year, being over 60 per cent. for boys and over 65 per cent. for girls on the basis of weight; and in the neighborhood of 50 per cent. for both sexes on the basis of surface. The variability upon the basis of surface is noticeably less than upon the basis of weight for other ages also.

Influence of Sex on Basal Metabolism.—Signs of a sex difference in metabolism appear in the very early work of Andral and Gavarret[2] and of Scharling;[169] but it is not until the classic investigation of Sondén and Tigerstedt[187] that definite proof is furnished. While the conditions of experimentation were not those recognized today as essential to demonstrate a basal difference, the authors are very positive in their opinion that under like conditions in the young the CO_2 output both per kilogram of weight and per square meter of surface (Meeh) is considerably greater in males than in females (p. 683). The average difference for their age series is as 140: 100. "This difference appears to vanish gradually with increasing age until in old age it disappears completely."

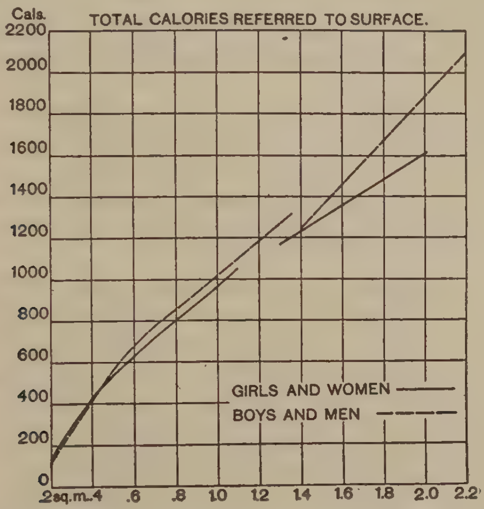

FIG. 234.—Chart showing basal metabolism of boys and men compared with that of girls and women on basis of body surface. (Benedict and Talbot, Carn. Inst. of Wash. No. 302, 1921, Fig. 49, p. 180.)

DuBois[49] first drew attention to a probable difference of basal metabolism between the sexes in children (Fig. 202, p. 549) upon the basis of the observations of Magnus-Levy and Falk,[109] who did not themselves recognize such a difference. Its demonstration, however, is due to Benedict and Talbot.[24] They find that the absence of a sexual difference for the very young infant (p. 604) "persists until about the weight of 11 kg., but that frequently there is a tendency for the boys to have a somewhat higher metabolism (average) than girls of the same weight" (Fig. 233). On the basis of surface they find that the two sexes remain at essentially the same metabolism (average) until the surface reaches 0.48 square m. (DuBois). "From this point the line for the boys rises above that for girls and there is no evidence of a tendency for the two lines to cross later" (Fig. 234).

Influence of Puberty.—Andral and Gavarret[2] maintained that with boys the carbon dioxide output suddenly increased at the age of puberty, while with girls it just as suddenly ceased to increase at this critical point. As pointed out by Sondén and Tigerstedt and by

Benedict and Talbot the conditions in these early experiments were far from basal. Sondén and Tigerstedt give the following comparison of the total CO_2 output for different age groups using that of a man 57 years of age as 100.

9 to 12 years	98
13 to 19 years	126
22 to 25 years	111
34 to 44 years	105

The combustion in the body of male individuals from 13 to 19 years of age is therefore greater than that of younger or older individuals of the same sex. This coincides with the period of most rapid growth in length (fifteenth year) and the most rapid growth in weight (sixteenth year).

In a remarkable series of observations on 200 boys ranging from 9 to 19 years of age Olin[134] finds, in agreement with Sondén and Tigerstedt, that the CO_2 output whether as total elimination or on the basis of body surface (see below p. 681) shows a distinct elevation for the age of puberty (14 to 16) above the general trend of the metabolism for the entire group.

The first work carried out on the same youths just before and just after the attainment of sexual maturity was that of DuBois[49] and his collaborators.[135] Eight normal boys were studied in the respiration calorimeter when they were 12 and 13 years of age and again two years later when they were 14 and 15 years of age. On both occasions the boys were placed in the respiration chamber four or five hours after a very light breakfast, which has been shown with adults to leave the basal metabolism unaffected, and were observed for two or three consecutive hourly periods while lying quietly, but for the most part awake. In the first series of observations the basal metabolism was found to be 25 per cent. higher than the adult level per unit of surface (linear formula), while in the second, after puberty had been definitely established, in four of the eight subjects the metabolism was on the average only 11 per cent. higher than the adult level. Benedict and Talbot very properly criticise these observations as failing to establish definitely by a sufficient number of observations the true basal, and point out that if the quieter periods of the first series be selected the metabolism is very close to that found in the second series. It might be urged further that there were at the time of DuBois' observations scarcely a sufficient number of basal experiments in the literature at ages preceding and following the ages of his subjects to warrant the inference of a distinct rise in metabolism at the prepubescent age above that of adjacent ages. Benedict and Talbot in a few scattered observations on boys and girls of prepubescent age find no such increase, but they admit that their experiments are not yet sufficient in number to warrant a definite conclusion. Whether the ripening of the sexual elements with the numerous attendant secondary effects upon the body exercises an influence upon the basal rate of oxidation must therefore be left undecided.

The Influence of Food upon Metabolism of Children above Nursing Age.—No perfectly satisfactory experiments directly upon the dynamic effect of food in children of this age group have ever been made. Here is a field of considerable promise for future work. Enough evidence has been cited in page 635 to prove that fat and protein at least do exert their specific effects upon the metabolism of infants less than one year of age, and it is certain that when larger meals are taken by children above this age the same effects are present, the net total effect being dependent upon the exact composition of the meal. Peculiar difficulties are encountered in attempting to separate the effects of the different food stuffs in children because of the restlessness usually produced by hunger and the consequent failure to obtain a true base line from which the specific effects can be gauged. Benedict and Talbot[24] have reported some fragmentary observations on younger children (p. 637) in which the metabolism was followed in successive periods up to 10 and 11 hours after a meal, a minimal level being attained at from 5 to 10 hours from feeding. Reckoning back from this basal to the earlier periods after food in which the muscular activity was equally controlled, a dynamic effect amounting to as much as 20 to 30 per cent. was sometimes seen. If it can be shown that a really basal rate can be attained in this way the method should prove useful with older children.

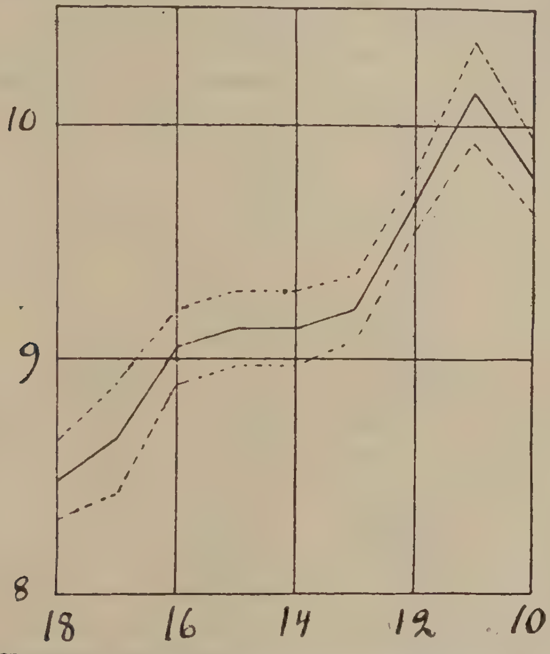

Fig. 235.—Chart from Olin showing relation of carbon dioxide elimination on basis of body surface to age. ———— mean, . . . limits of variation. (Skandan. Arch. f. Physiol., 1915.)

The Influence of Muscular Activity.—The extensive observations of Sónden and Tigerstedt at Stockholm, of Rubner[157] at Berlin and of v. Willebrand[205] at Helsingfors in contrast with the very low if not actually minimal values obtained by Magnus-Levy and Falk at Berlin, by Olin at Helsingfors and by the Boston workers, furnish some very interesting, though as yet very incomplete, data on the effects of moderate muscular activity.

The resting and post absorptive rate established by Magnus-Levy and Falk have been discussed above under the heading of basal metabolism, and while the average line established by them lies considerably above that of Benedict and Talbot (Fig. 230, p. 676) their results lie within the range of variability given by the latter authors. So also do those of Olin, notwithstanding that her subjects were studied in the sitting position. This series comprises observations on some 200 boys between the ages of 9 and 19. They were placed in the apparatus individually, usually in the morning after a light breakfast. The results for 162 subjects are summarized in the following table. In calculating the surface area by Meeh's formula the constant 12.205 was used by Olin for boys under 13 and 12.847 for boys over that age. The heat production in relation to surface area calculated by the writer upon the assumption of a R.Q. of 0.85 is very close to that ordinarily obtained upon adult subjects under the conditions usually accepted as basal (p. 548). It has recently been shown[186] that a person propped up in a semi-reclining position may have a metabolism even lower than when lying flat in bed. These results by Olin seem to signify that young persons may be induced to sit quietly enough to exhibit a metabolism even lower (?) than when lying down. It would seem that Olin's subjects must have been supported in such a position as to require no muscular tension and that in the semi-reclining position, as in a

Table 43.—Metabolism of Boys Sitting Very Still (Olin)

Number of subjects	Average age	Average weight Kgm.	Body surface (Meeh) Sq. M.	CO_2 per kilogram and hour	Heat production* per square meter and hour
4	9	35.9	1.299	0.425	34.1
15	10	31.5	1.217	0.505	37.9
14	11	36.1	1.327	0.492	39.3
27	12	38.1	1.396	0.479	37.5
26	13	43.1	1.573	0.452	35.7
22	14	49.6	1.726	0.425	35.3
19	15	52.9	1.805	0.412	35.3
18	16	59.2	1.948	0.399	35.0
9	17	55.4	1.864	0.385	33.5
7	18	65.6	2.086	0.359	32.8

* Assuming a R.Q. of 0.85, *i.e.*, heat-value for CO_2 of 5.721 calories per liter.

steamer chair the diminished pressure of the abdominal organs upon the diaphragm may have lessened the muscular effort of breathing. The results should probably be regarded as representing truly basal conditions.

In strong contrast with these are the figures obtained by Sondén and Tigerstedt upon groups of six boys and girls of approximately the same age. The authors state that their purpose was to obtain data which would be of value in determining the ventilation requirements of public assembly halls and especially school rooms. Their subjects were required to sit as still as they would in school, but were permitted to handle and read books and at times to nibble candies and fruits. Their results follow.

TABLE 44.—METABOLISM OF CHILDREN SITTING AS IN SCHOOL (SONDÉN AND TIGERSTEDT)

Average age		Average weight kgm.	CO_2 per kilogram and hour, grams	Calories* per square meter (Meeh) and hour
Years	Months			
		Boys		
7	10	20.1	1.149	73.1
9	7	27.5	1.207	83.1
10	6	30.2	1.106	78.6
11	5	31.6	1.063	76.7
12	6	34.1	0.997	72.1
13	10	44.5	1.000	75.0
14	6	45.3	0.960	74.2
		Girls		
7	10	21.8	1.133	74.1
9	11	26.6	0.850	57.8
11	2	31.0	0.845	60.6
12	2	36.2	0.743	56.1
13	4	39.5	0.696	51.4
14	0	44.3	0.661	50.7
15	2	48.6	0.562	44.5

* In view of the fact that the children of this series were permitted to eat candy and fruit at times while in the respiration chamber a R.Q. of 0.90 is assumed, *i.e.*, the CO_2 is given a heat value of 5.471 calories per liter.

The heat production here is calculated upon the assumption of a R.Q. of 0.90 employing the values for CO_2 given by the authors upon the basis of a square meter of surface. The results are nearly double those obtained by Olin. Benedict and Talbot have calculated the heat production per kilogram and 24 hours of these subjects on the assumption of a R.Q. of 0.90 and these values are shown for comparison upon a chart (Fig. 230) prepared by them to exhibit the basal metabolism according to several authors. Table 44 shows a very marked difference between boys and girls which is even greater than the difference in basal metabolism between boys and girls (Fig. 233) of the same age. This is due to the greater degree of composure readily induced in girls of the adolescent age.

Sondén and Tigerstedt give the following values for two of their boys during sleep:

Boy of 11 years, 3 months.....	14.09 gm. CO_2 per square meter (Meeh) and hour
Boy of 12 years, 3 months.....	13.78 gm. CO_2 per square meter (Meeh) and hour

From which we may derive the following heat production on the assumption of a R.Q. of 0.88. Boys of the same age in school showed

Boy of 11 years, 3 months..............	35.1 calories per square meter and hour
Boy of 12 years, 3 months..............	34.3 calories per square meter and hour

a heat production of fully twice as much (Table 44).

Von Willebrand's observations were made upon boys from 9 to 14 years of age in the same apparatus as used by Olin. They were confined for the entire 24 hours, taking all three meals in the apparatus. They went to bed at 8 to 9 p.m. and rose in the morning about six o'clock. In some instances the subjects slept for a short time during the day. The difference between waking and sleeping metabolism for four individuals is shown in the following table somewhat modified from one given by Benedict and Talbot.

TABLE 45.—METABOLISM OF BOYS AWAKE AND SLEEPING (VON WILLEBRAND)

Name	Age, years	Body weight, kilograms	Calories* per square meter and hour	
			Awake	Asleep
Veikko..................	9	25.9	57.8	27.3
Viktor..................	10	30.8	49.0	32.0
Julius..................	13	34.1	47.6	24.9
Silo..................	14	36.5	38.9	20.4

* Meeh's formula using 12.205 for the first two boys and 12.847 for the second two. Heat is calculated from the CO_2 assuming a R.Q. of 0.88.

Rubner's experiments were made upon two brothers, one fat and one thin, the sons of parents of slender means and therefore not likely to be overfed. They were confined for about 22 out of the 24 hours in the respiration chamber, ate and slept there and during waking hours were permitted to move about, even walking some. The following summary of the results is given by Lusk.[105]

Comparative Estimates of Physiological Needs for Food (In Calories).

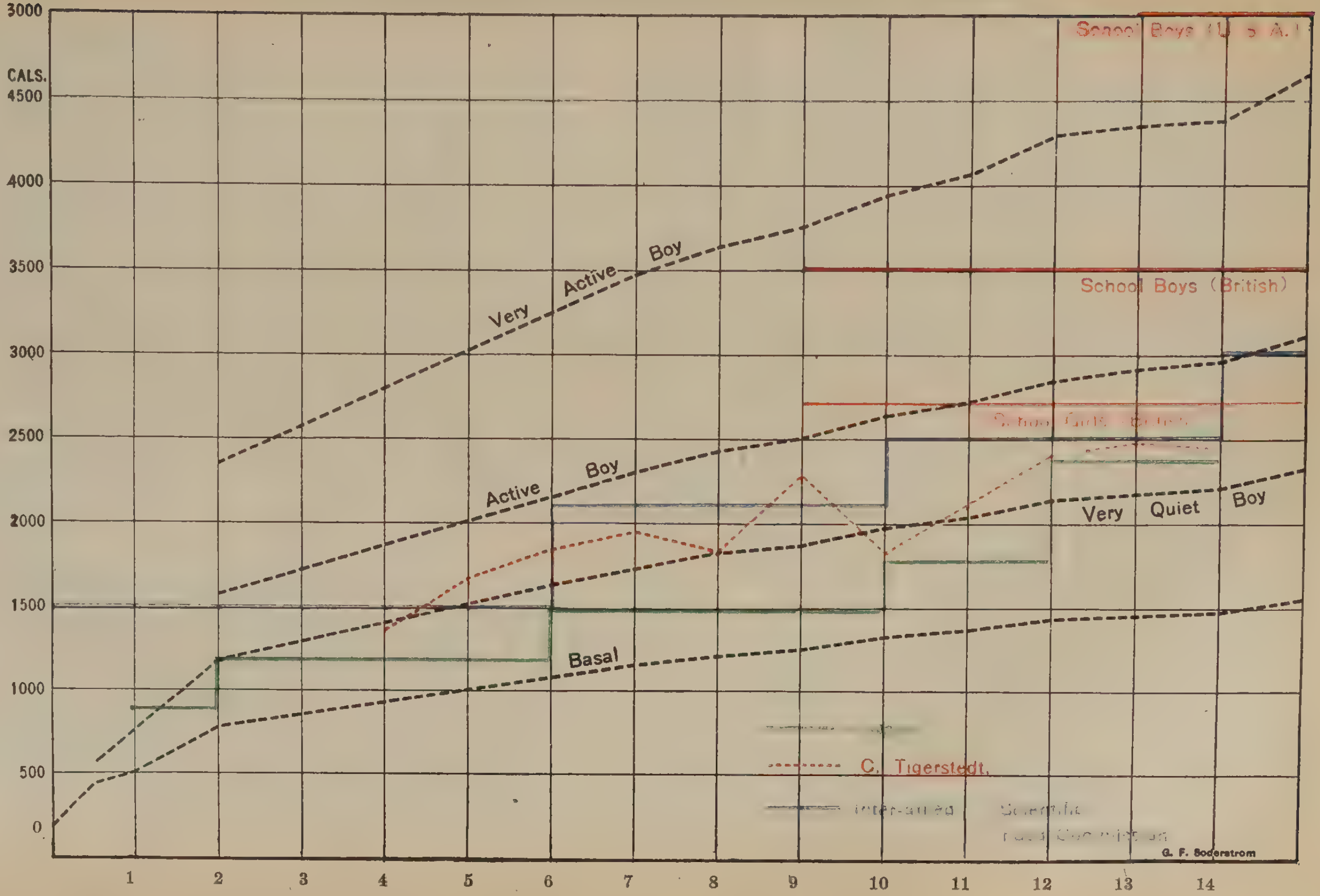

FIG. 236.—Comparative estimates of physiological needs for food of growing boys and girls. (Lusk, Journ. of Home Econ., Balto., 1919, xi, p. 281.)

TABLE 46.—METABOLISM OF A FAT AND THIN BOY (RUBNER, AFTER LUSK)

	Age, years	Weight, kilograms	Heat production		Per square meter (Meeh)	
			Total for 24 hours	Total kilograms and 24 hours	24 hours	Per hour
Fat boy.......	10	41	1786.1	43.6	1321	55.0
Thin boy......	11	26	1352.1	52.0	1290	53.7

The last column may be compared with the results of v. Willebrand (Table 45) and those of Sondén and Tigerstedt (Table 44).

A most interesting phase of the activity metabolism in children, namely, the muscular efficiency as compared with adults, has never been studied. Nor has any attempt been made to estimate the actual energy expenditure of an active child for the entire 24 hours. How much the values just given for boys who were permitted to move about to a limited extent in the respiration chamber falls short of the actual daily requirements with its large quota for growth may be gained from the accompanying chart taken from Lusk[106] (Fig. 236).

Estimates of food intake by normal children may, if sufficiently prolonged, give a very excellent idea regarding the energy requirement. A number of such estimates have been made particularly by Camerer,[36] Uffelmann[194] and Herbst[74] in Germany, by C. Tigerstedt[191] in Finland and by Gephart[62] Lusk[106] and Holt[77] in this country.

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SUBSTANCE METABOLISM

As remarked previously the substance metabolism has to do chiefly and fundamentally with the metabolism of proteins, since these materials constitute the substrata of living protoplasm. We think of the salts as perhaps next in importance in maintaining the structural integrity of the tissues and of the non-nitrogenous organic materials, fats and carbohydrates, if we think of them at all under this category, as merely accessory. If space permitted it would be of interest to inquire how far this tendency to regard fat and carbohydrate merely as fuel is justified. One instance readily comes to mind in which fat or at least lipoid matter is of obvious importance structurally; namely, in the nervous system; but since the science of nutrition has as yet learned very little of the influence of food upon the nervous system, little could be developed in this direction. It has been thought best, therefore, to limit the discussion in this chapter to those phases of the substance, contrasted with the energy, metabolism which seem to be of greatest practical import; namely, the physiology of protein and salt metabolism. The utilization of fat, falsely called "fat metabolism," is discussed in its proper place, but the intermediary metabolism of fat and carbohydrate is entirely omitted, because so far as the writer is aware they run exactly the same course as in adults and numerous works are available setting forth the existing knowledge of this most engaging subject.

A. Digestion and Absorption

Mechanical Factors. Mechanics of Suction and Swallowing.—The act of taking food in the newborn infant is wholly dependent upon the power of suction in the mouth. The descent of the lower jaw increases the diameter of the mouth cavity in the vertical (really dorsoventral direction). With air-tight closure of the lips and sucking pads about the nipple anteriorly, air-tight closure by pressure of the tongue against the palate posteriorly, and the resistance offered by the suction pads in the cheeks, a negative pressure is created which increases the flow from the breast or bottle to the mouth. Auerbach[24] distinguished this type of suction, which he called the infantile type, from the inspiratory type, which, he says, prevails in the adult. The infantile type of suction, however, is often employed by an adult, as for example, in smoking a pipe. The act of suction in the newborn is a pure reflex. Its nerve paths have been studied and the center located in the medulla.[29] Cramer[83] and others have studied the mechanics of suction and in general agree that the inability to nurse well is attributable primarily to an imperfect nervous mechanism rather than to a weakness of the jaw muscles. By making a tubulure into the nursing bottle and connecting it with a recording tambour a series of regularly succeeding curves of negative pressure caused by sucking may be demonstrated, which are rather definitely assignable each to a separate component of the series of muscular acts involved.[221]

Swallowing ordinarily does not occur until a sufficient quantity of milk flows into the mouth to spread over the base of the tongue and reach the uvula or fauces thereby eliciting the reflex contraction of the mylohyoid muscle. This may require several suction movements of the jaw, depending upon the freedom with which milk flows from the breast or nursing bottle. Swallowing likewise is a peculiarly complicated reflex act. The peristaltic wave beginning in the constrictor muscles of the pharynx descends at a uniform speed over the entire length of the esophagus until it arrives at the cardia. The muscle wave, however, does not proceed at the same speed as does the liquid food in its passage through the esophagus. A spurting sound may often be heard over the cardia indicating entrance of the food into the stomach in four to six seconds after inauguration of the act. The peristaltic wave is propagated from section to section of the esophagus by a series of reflex motor impulses coming from the medullary center and spreading over various branches of the laryngeal nerves. Even when a section of the esophagus is removed the peristaltic wave will appear in the lower segment at its appropriate time, having jumped the gap by way of the reflex arc. Section of the laryngeal nerves abolishes the coördinated character of the act of swallowing, the upper part of the tube becoming relaxed while the lower part including the cardia enters a state of tonic contraction.

The afferent impulses from the fauces for the swallowing reflex are carried by the second division of the fifth nerve, the glossopharyngeal and the pharyngeal branches of the superior laryngeal. Efferent impulses travel by the hypoglossal nerve to the muscles of the tongue, by the fifth nerve to the mylohyoid and by the glossopharyngeal, the vagus and the spinal accessory nerves to the muscles of the fauces and pharynx. The medullary center is in reality a chain of centers, the entire series of discharges from which may be elicited by a single stimulus. This entire mechanism is developed and is functional at birth, even some months before term.

Elicitation of the series of reflexes involved in suction and swallowing varies with hunger and with appetite. Hunger distinctly lowers the threshold, making it easier to start the sucking motions. This is quite independent of experience and probably operates to induce sucking in the newborn the moment anything touches its lips; for as we shall see presently the infant is born hungry. Appetite, on the other hand, implies memory of pleasurable sensations from previous experience and cannot play any part until a mechanism for memory is developed.[67] Defensive reflexes which may cause the rejection of injurious substances from the mouth are likewise developed and operative at birth.

The milk as it runs through the mouth is mixed with saliva. Since the normal food of the infant is entirely fluid, and is therefore easily swallowed, the amount of saliva provided at birth is very small and probably does not exercise any influence on deglutition. Such physical action as it exerts takes place in the stomach (p. 723). Later in infancy saliva may be present in sufficient quantity to modify the coagulation of the milk and to moderate the reaction of the stomach.[7]

Movements of the Stomach.—It has been demonstrated that the contractions of the stomach appearing when the stomach becomes nearly empty, and known to be the cause of the hunger sensations, are even more intense in the infant than in the adult.[68] In accordance with this fact it is a matter of common knowledge that the young experience greater hunger than do adults. Carlson points to at least three physiological reasons for this greater hunger in addition to the greater demand for energy which has been fully discussed in the previous chapter: (1) There may be a greater rate of secretion of gastric juice so that digestion in the stomach requires less time, thereby giving a more continuously empty stomach. (2) There may be relative hypermotility of the filled as well as the empty organ because of the actual youth of the stomach muscles, because of greater motor innervation from the brain by way of the vagus, or as the result of greater concentration of specific chemical stimuli in the blood resulting from a higher rate of metabolism. (3) There may be greater sensitiveness to afferent impulses on the part of the brain centers concerned in the hunger sensation.[67]

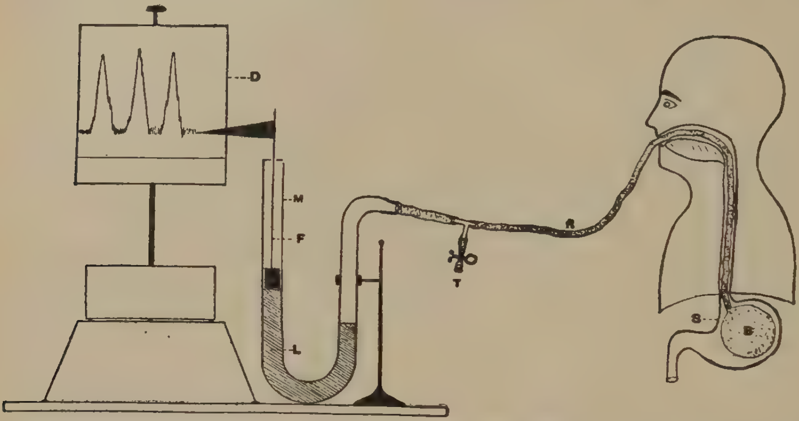

Fig. 237.—Diagram showing method of recording hunger contractions of the stomach. (Carlson.) B, rubber balloon in stomach. D, kymograph. F, cork float with recording flag. M, manometer. L, manometer fluid (bromoform, or water). R, rubber tube connecting balloon with manometer. S, stomach. T, side tube for inflation of stomach balloon. (The Control of Hunger in Health and Disease," Chicago, 1916, p. 35.)

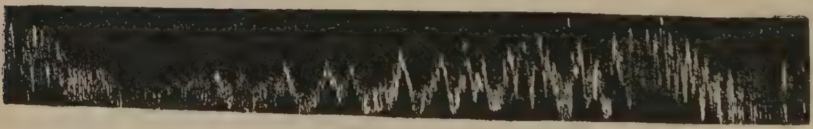

Fig. 238.—A period of gastric hunger contractions of a nine-hour-old normal infant before first nursing. (Carlson, "The Control of Hunger in Health and Disease," Chicago, 1916, p. 41.)

In the newborn and very young infant the period of quiescence between spells of hunger contractions is much shorter than in the adult (10 to 60 minutes as against one to three hours). Carlson is of the opinion that the hunger contractions may be the cause of restlessness in sleep or when of unusual intensity may cause the infant to wake up and cry. This would seem to be a simple biological provision to insure food as needed. On further inquiry, however, it is found in the normal breast-fed infant on the one hand that contractions of great intensity may occur without arousing the infant from sleep, and on the other hand that crying can often be allayed without stopping the contractions. Therefore, others[422] believe that hunger *per se* is not a primary cause of crying and they cite the common observation that newborn infants particularly may be deprived of food for a considerable time without showing any sign of discomfort. They infer that the distress accompanying hunger becomes more acute the older the child becomes, and that crying is rather a matter of nervous organization than of teleology. One fallacy in this line of reasoning may be exposed by the fact that, even in the adult, longer deprivation of food may cause less discomfort than a short period of hunger. Professional fasters testify that after the first day or two one does not experience any particular desire to eat. The greatest discomfort from the stomach comes within a few hours (6 to 10) from the usual time of eating. After the first two or three days the contractions diminish in intensity and the subjective pangs associated therewith are very much mitigated. The same is probably true of the infant in a shorter fast. External signs of distress from lack of food may not of necessity coincide with the most intense contractions. Nervous irritability may be influenced by hunger,[151] and crying may result as much from this change in irritability as from the gastric contraction. At all events it would be difficult to convince an average mother that her infant does not cry because he is hungry.

Food placed in the mouth does not inhibit increased contractions in the very young infant. Inhibition from this source appears later. But when a very small quantity of milk (20 c.c.) or water is introduced into the stomach during a period of contractions, inhibition invariably results. The origin and increasing intensity of these contractions are thus summarized by Taylor:[422] "Immediately following food the infant sleeps. The upper stomach muscles retain a tonic grasp upon the food. The pyloric antrum is traversed by peristaltic waves.[63] The stomach gradually empties. The point of origin of the peristaltic waves rises higher and higher toward the cardia. The tonus rhythm of the fundus begins, the stomach empties itself more completely, the tonus rhythm becomes more intense, and the first hunger contractions appear.[371] The first contraction period is apt to be short. After a wait of perhaps 20 minutes a longer and more intense hunger period appears, then another and another. The infant's sleep becomes lighter. He is more easily awakened by external stimulus or by gastric discomfort. He is put to the breast, nurses vigorously, becomes fatigued, or experiences satiety from distention and again goes to sleep."[391]

The time interval from feeding to the reappearance of hunger contractions was found by Carlson and by Rood Taylor to be on the average two and one-half hours, with the minimum at one and one-half hours and the maximum at three and one-half hours. Contractions usually appear some time before the stomach is completely empty.

Evacuation of the Stomach.—Roentgenological study of the infant's stomach has given much new information regarding the shape and motility of that organ. This information can be summarized here only very briefly. The shape of the gastric shadow upon the fluoroscopic screen or upon the Roentgen plate depends quite as much upon the air included in the viscus as upon the amount of food. Pisek and LeWald[352] distinguish three definite forms: one the ovoid or Scotch-bagpipe form, of Flesh and Pietri; second, the tobacco-pouch or retort shape of Alwens and Husler; third, a pear-shaped organ with base above and to the left. The total space occupied by the stomach may be much greater than one would suppose from a study of the infant cadaver. The shape and extent of the viscus also will depend upon the posture of the body.

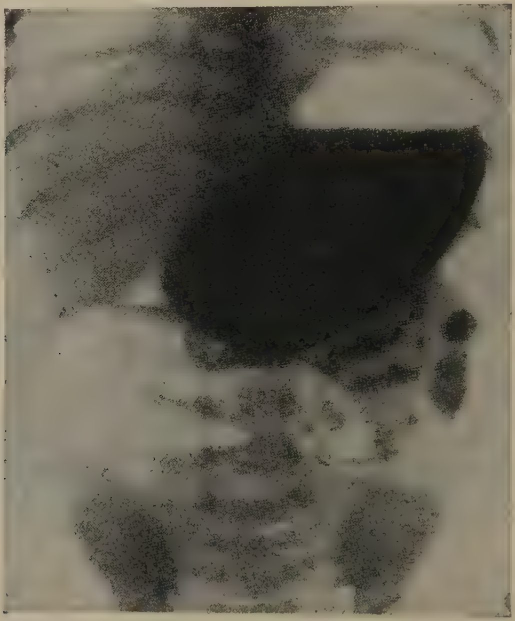

FIG. 239.—Roentgenogram of stomach of nursing infant 4 days old, taken 2 minutes after infant had received 1¾ ounces of food. Note food already in jejunum. (Pisek and LeWald, Amer. Journ. Dis. of Children, 1913, vi, p. 232, Fig. 5.)

A bismuth meal of milk may be seen discharging into the intestine within five minutes after it is received in the stomach, and in many cases the entire meal is evacuated within one hour. The average time, however, on children with an exclusive milk diet is one and one-half to two hours. Individuality seems to play quite a strong part. One child after 100 c.c. of mother's milk will exhibit an entirely empty stomach in two and one-half hours, while another with exactly the same amount of milk will require three hours for emptying. Also with the same quantity and dilution of cow's milk, one child may empty in 60 minutes a quantity which would require another child 90 minutes to dispose of. Doubling the quantity of milk in the same child increases the time of emptying only a little. From this one may reason that a few large meals will keep the stomach less active in total time than a larger number of small meals.

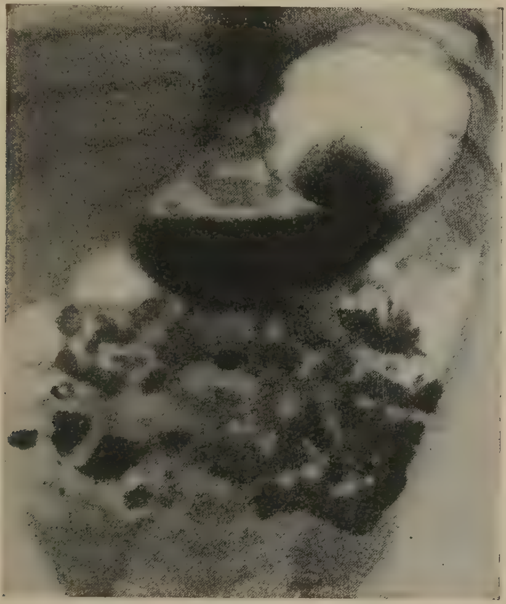

Fig. 240.—Same infant as Fig. 239, thirty minutes later. Greater part of food is in the intestine. Note large air bubble and evidence of segmentation in the intestine. (Pisek and LeWald, Amer. Journ. Dis. of Children, 1913, vi, p. 232, Fig. 6.)

The most important single factor, so far as the character of the food is concerned, in infants as in adults, is the amont of fat. Tobler and Bogen[429] give the following contrast. Increasing the amount of fat from 0.6 to 7.2 per cent. of the milk, delayed evacuation of the stomach from 70 minutes with the poor milk to 150 minutes with the rich milk. The concentration of the milk, independently of the per cent. of fat, likewise influences the time in the stomach. The more concentrated the longer it remains. Dilution of cow's milk, therefore, keeping up the per cent. of fat will favor discharge of the stomach contents, but too great a dilution acts unfavorably. Schüle has observed that 300 c.c. of milk sipped very slowly will remain 25 to 30 minutes longer in the stomach than if it is taken all at once.

Before the introduction of the Roentgen rays, it was learned through the use of the stomach sound that, in breast-fed infants less than a week old, the stomach is often found empty within one hour after feeding. Beyond one week but in the first month the maximum duration was found to be one and one-fourth hours. With still older infants, and especially those fed upon cow's milk, the stomach was rarely empty inside of two hours. Clarke[72] employing a modification of the sound method, in an extensive series of observations, concludes, in agreement with the Roentgenological studies, that the motility of the infant's stomach varies inversely with the concentration of the food. The more dilute the food, therefore, the more frequent the feedings may be.

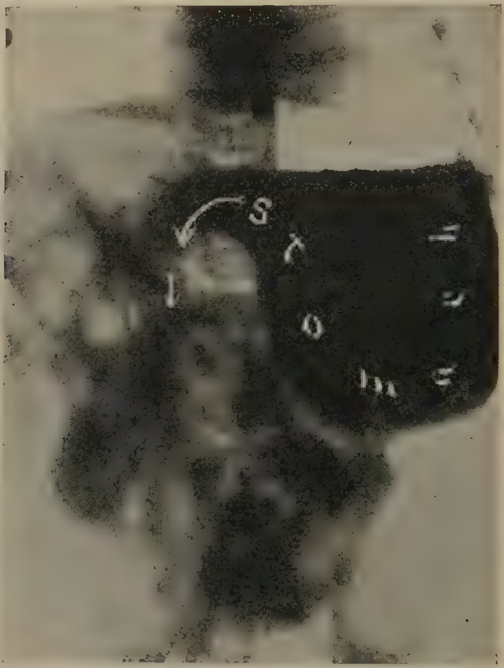

Fig. 241.—Retort-shaped stomach of infant 4 months old, artificially fed; malnutrition; 125 cc. Bismuth-milk mixture; Roentgenogram 8 minutes after feeding. Stream of food pouring out. (Pisek and LeWald, Amer. Journ. Dis. of Children, 1913, vi, p. 232, Fig. 15.)

Recent studies on the influence of the body posture on the emptying time of the stomach in infants from six weeks to seven months of age, using the Roentgen ray, confirms previous ideas regarding this matter. Eructation of gas is facilitated by an upright position immediately after nursing and by a prone position with the head of the bed slightly elevated.[407] The evacuation of the stomach, however, is most rapid in the right lateral position.[104] The reason for this is obvious, since the junction between the stomach and intestine is on the right side. A supine position produces a comparatively slow emptying.

A number of observers using the Roentgen ray with adults have found the stomach contents at the end of a meal distinctly stratified. This has been confirmed by examination of the frozen viscus in the case of animals. With infants taking fluid food entirely there is likewise a tendency to stratification, and in some instances the layers may be quite distinct. This, according to Gruetzner and Sick, results in expulsion of the whey first, the casein next, and then the fat.

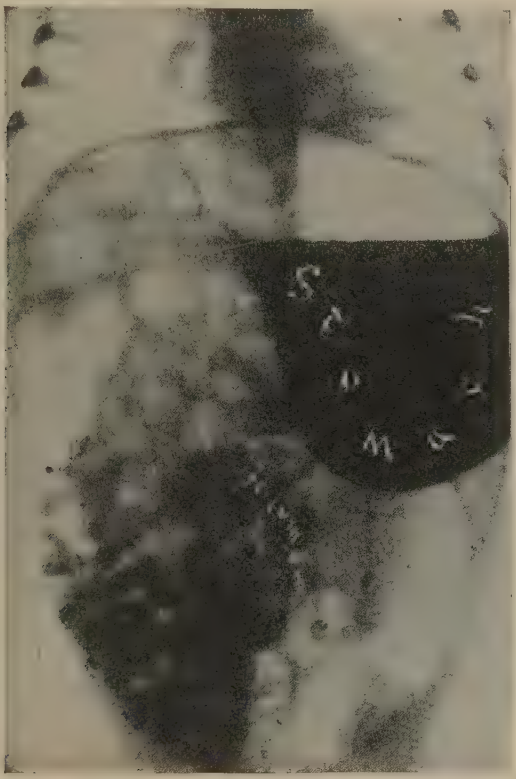

Fig. 242.—Same child as Fig. 241, after 15 minutes. Note gas in cardiac pole, pushing heart upwards. (Pisek and LeWald, Amer. Jour. Dis. of Children, 1913, vi, p. 232, Fig. 16.)

The stomach of the infant in contrast with the adult organ exhibits very slight, if any, peristalsis.[251] Ladd observed that in normal digestion a bismuth meal appears in the intestine as soon as the feeding is completed, showing that a considerable amount of food may escape gastric digestion altogether; also that when a bismuth feeding is given and another follows at the end of the regular two and one-half or three hour interval, a residue from the first feeding does not mix well with the new feeding and passes out into the intestine much more quickly than when left to itself. A moderate degree of distention favors peristalsis.

It should be borne in mind that the reason milk can pass directly from the cardia to the pylorus and thence to the duodenum without entering the fundus of the stomach is an anatomical one, the so-called "gastric canal." This fact has been well brought out by Hess[189] in his use of the duodenal balloon catheter. The gastric canal or short path which the food can take at the beginning of a meal lies in a vertical rather than a horizontal direction (Fig. 243). The stomach when filled, however, tends to take a distinctly horizontal position, if the infant is on its back. Held in the vertical position the stomach conforms, as would be expected, through the influence of gravity, the pylorus being considerably more movable than the cardia.

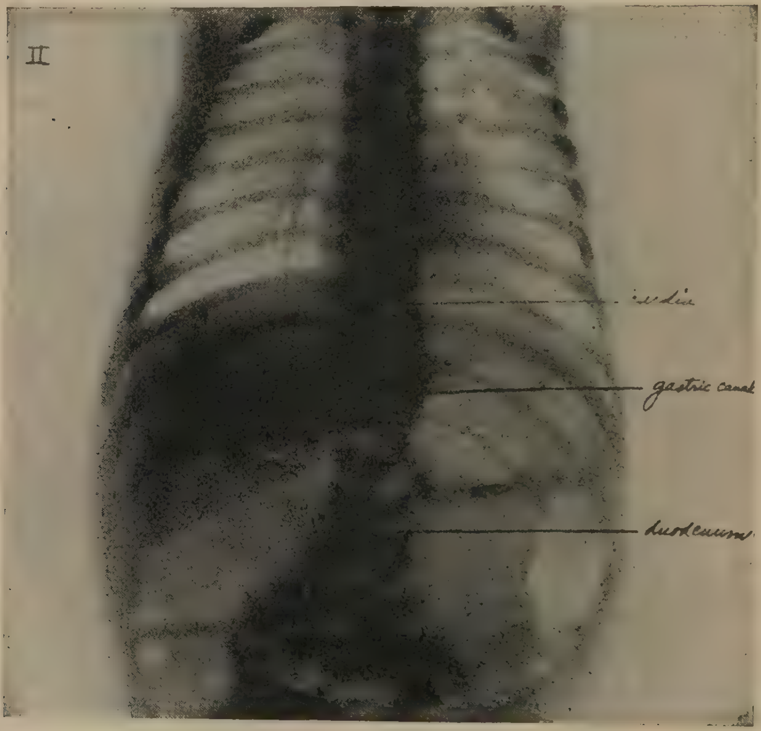

Fig. 243.—Balloon catheter in duodenum of an infant, and outlining course of the gastric canal from cardia to pylorus. (A. F. Hess, Amer. Journ. Dis. of Children, 1914, vii, p. 433, Fig. 5.)

The adult type of stomach is acquired at about two years of age. Hence in children taking a mixed diet the evacuation of the stomach, it may be presumed, follows more closely the adult type of motility. This has been well described by Hertz,[184] who has confirmed in a general way the observations of Cannon[61] on the cat. The body of the stomach according to Hertz, is divided into two rather distinct portions by the transverse band, or *incisura angularis*, confined in man chiefly to the lesser curvature. The pyloric portion consists of the vestibule and pyloric canal which is especially well marked in the infant. . When a small portion of food is swallowed it takes the shorter course along the gastric canal to the pylorus. After a large meal peristalsis begins at once, the contractions starting well up on the body of the stomach and deepening in their progress toward the pylorus, as the muscle coat becomes thicker. When the contraction groove reaches the pyloric vestibule it is so deep that it almost completely cuts off the pyloric end from the rest of the stomach. There follows a compression movement by contraction in all directions which results in squeezing the vestibular contents out, part going through the pylorus and part escaping backward as a reflux stream into the body of the stomach. These contraction waves succeed each other at regular intervals of 15 to 20 seconds (in the adult) and continue thus to force the food little at a time into the duodenum.

Emptying of the stomach in the adult is closely related to the acidity of the contents. A strongly acid reaction exerts an inhibitory effect upon the pyloric sphincter causing it to relax and thereby permit the food to pass. Cowie and Lyon[81] have demonstrated the presence of this so-called pyloric reflex in the infant and that the food is delayed in its passage by administration of alkali. The latter observation was confirmed by Pisek and LeWald. It should be noted, however, that in the light of the most recent contributions both by the Roentgenological[79] and graphic[274] methods there is positive evidence that in the movements of the stomach in the adult there is a correlation between marked motor activity of the stomach, either as tonus changes or peristaltic waves, and an inhibition of the pyloric sphincter. The discharge of gastric contents is not governed by the presence of free acid alone. Cowie and Lyon observed in their infants likewise that "free acid is not necessary for pyloric opening."

Movements of the Intestine.—If a section of the small intestine is cut out of an animal and immersed in a physiological solution, such as Ringer-Tyrode solution, and kept warm, it is seen to exhibit a series of rhythmic contractions which travel as waves along the muscle coats. Stimulated by the presence of food inside, the intestine *in situ*, but isolated from the central nervous system, sends its waves always in the same direction, namely, toward the large intestine. Bayliss and Starling[31] observed that in a progressive contraction of this sort there is always a region of relaxation immediately in front of the region of constriction. This phenomenon, which is common to the alimentary tract from the lower part of the esophagus to the rectum, was called by them the "law of the intestine." That the immediate stimulus to this behavior is the mechanical effect of food rather than chemical has been demonstrated by introducing a lump of cotton lubricated so that it will slip easily along the mucous coat. Cannon[64] suggested the name "myenteric reflex" for the same series of phenomena, and Magnus[279] demonstrated that the plexus of Auerbach is necessary for its manifestation. Gaskell[147] has observed that in certain invertebrates there are neurones of which the axons branch into two fibers, one because of the manner of its termination causing contraction of a certain muscle the other by a different form of termination causing inhibition of another muscle, and has pointed out that if the vagus, whose terminal branches are known to connect with the plexus of Auerbach, may be assumed to send an inhibitory fiber forward and an excitatory fiber backward, a complete nervous mechanism would be provided for regulation of the intestinal movements. To account for progressive waves in the isolated segment, however, it is necessary to suppose that a mechanism sufficient for its regulation exists in the wall of the intestine itself, and Dogiel[102] has shown that each neurone of Auerbach's plexus has two axons which have different destinations. Further, it is claimed[13] that the rhythmicity, irritability and latency of the intestinal muscle decrease regularly as one proceeds from duodenum to colon. When the reaction to potassium cyanide and to anesthesia is tested and production of CO_2 and the content of catalase determined in the different segments there is a gradual falling-off in metabolic activity in the same direction, the diminution being described as a "metabolic gradient." This peculiarity of the intestinal muscle, quite independently of the nervous system, is held to be sufficient to explain the direction of peristalsis.

Under certain circumstances contraction waves may proceed in the opposite direction and are commonly spoken of as anti-peristaltic waves. Cannon[62] has suggested that the downward-moving contractions should be called *katastalsis* and the upward-moving contractions *anastalsis*. Both anastalsis and katastalsis occur, according to his observation, in any portion of the gastro-intestinal tract. They are likely to occur rhythmically and run in a close series with no preceding inhibition. The contraction, which is preceded by a demonstrable region of inhibition, is of a different order; it is managed by the myenteric reflex and always moves downward. Since its characteristic feature is the relaxing or opening of the canal in front of the constriction the name *diastalsis* was suggested. Cannon finds that katastalsis occurs typically in the stomach and that anastalsis occurs typically in the proximal or ascending colon.

A second form of movement in the small intestine is that described by Cannon under the name rhythmical segmentation. Its essential features are described by this author as follows: When the food has been distributed evenly through the intestine (of the cat) a notable feature in most all of the loops is the total absence of movement. If the animal remains quiet, only a few moments elapse before peculiar motions appear in one or other of the loops or perhaps several simultaneously. These motions consist in a sudden division in one of the long masses of food into many segments of nearly equal size, then these segments are again suddenly divided and the neighboring halves unite to make new segments, and so on. The segmented appearance of the bismuth contents seen in most any radiograph (*e.g.*, Fig. 240, p. 699) of the infant's small intestine soon after feeding is due to this phenomenon.

The purpose of these motions cannot be doubted. Recurring frequently in the same segment they serve to mix thoroughly the contents of the organ and to bring them into intimate contact with the intestinal lining, thereby promoting both digestion and absorption. The rhythmical segmentation is always followed sooner or later by a diastaltic wave carrying the contents along to a new segment where the process of rhythmical division and mixture is repeated.

Emphasis should be laid on the fact that these rapid rhythmical segmental contractions can only be observed if the subject is perfectly quiet. They may be inhibited through fear, rage or almost any other kind of discomfort. Such inhibition is exerted so constantly that in the experimental animal it is practically impossible to demonstrate the myenteric reflex unless the splanchnic nerves are cut. The vagus control of the intestine is both inhibitory and motor. When stimulated it gives the inhibitory effect first and the motor effect only after repeated stimulation. Bayliss and Starling (*loc. cit.*) have published one experiment in which the motor effect of the vagus was demonstrated only in the ninth period of stimulation. The vagus is distributed to all parts of the alimentary canal except the two extreme ends. The anterior end has its nerve supply from the glossopharyngeal and the posterior end from the pelvic visceral, or autonomic nerves.

A third form of movement is often described for the small intestine namely the pendular, or swaying movement, caused by unequal contraction of the longitudinal muscles on two sides of a loop.

It is to be presumed that all of these types of motions are characteristic of infants and children no less than of the adult, although as noted above, the waves may not be so vigorous. Much remains yet to be learned regarding the neuro-muscular control of the alimentary canal in the infant although some progress has been made recently by the radiographic method. In time it may be expected that other peculiarities than those already mentioned will be brought out.

There is considerable evidence that hunger is due in part to contractions set up in the small intestine[67] as well as in the stomach. Since the gastric hunger contractions are known to be more intense than in the adult we may expect to learn that hunger peristalsis in the intestine of the infant is likewise more intense.

Movements of the Large Intestine.—In the adult digestion is practically completed when the intestinal contents reach the ileocecal valve (p. 738). What remains to be done is to squeeze the water out and reduce the mass to a consistency which can be retained until a convenient time for evacuation. It is reasonable to infer that this postponement of defecation together with the further possible extraction of nutrient values through the bacterial digestion of cellulose was of sufficient advantage in the evolution of the human form to overcome the disadvantage of such slight intoxication from bacterial putrefaction as might occur in a state of nature. The human colon is obviously of the herbivorous type and there is every reason to believe that primitive man lived much more largely on vegetable matter than does civilized man. Correspondingly, it is a rare individual who does not experience greater freedom from constipation and other intestinal intoxications when a liberal portion of his diet is drawn from fruits and fresh vegetables.

With the infant however, the struggle for existence would impose somewhat different conditions. The exclusive food for many months must be milk. Only upon such a concentrated dietary can he make the necessary growth and at the same time cover his requirements for heat which are paramount. The food does not remain long in the stomach—it is practically ready for intestinal digestion when it is ingested. Radiographic studies show that the sojourn is comparatively short in the upper part of the small intestine. The duodenum and jejunum both are usually found empty except immediately after a meal. The food is checked in its hurried course only in the ileum. The more readily available constituents like lactose are absorbed quickly—lactose even more quickly apparently than glucose,[194] but time is needed for the digestion and absorption of protein and fat. Recent studies[201] have shown that while total utilization of fats is remarkably good in normal infants, the *percentage of fat* in normal stools is much higher than in the adults. Moreover even a mild form of diarrhea causes the elimination of a very high percentage of fat and of other solids as well. Now radiographic studies show that the colon as well as the long sigmoid are practically always full. The relative capacity of the entire large intestine is much larger than in the adult. This disproportion is not required for bacterial digestion, for animal food like milk is perfectly digested without the aid of bacteria. The inference is rather clear therefore that a relatively greater amount of absorption must take place in the large intestine of the infant than in the adult. Direct proof, however, is lacking.

The mass delivered to the large intestine is still semifluid, a state of consistency quite necessary for complete contact with digestive enzymes on the one hand and with the absorption surfaces of the small intestine on the other. Now however the water begins to be absorbed rapidly by the colon, the sacculations of the colon serving to increase the surface, as the *valvulae conniventes* increased the absorption surface above the ileocecal valve. The consistency of the residual mass becomes rapidly more solid until when the transverse colon is reached the material may be found as firm as that discharged from the rectum.[65] Cannon has shown that it is especially in the proximal portion of the large intestine that the backward movements which he describes as anastalsis occur. This type of movement in this location has been confirmed for the adult by Rieder.[362] So far as the writer can learn it has not been seen on the fluoroscopic screen in the infant, but there is no reason to suppose it is altogether lacking. One would expect *a priori* that anastalsis, or anti-peristalsis, would be scarcely so well developed as in the adult, just as katastalsis is less well developed in the infant's stomach. The fact that infant's feces contain a higher percentage of water (78 to 81 per cent.) as compared with the adult on an ordinary mixed diet (65 to 67 per cent.),[411] also speaks for a more rapid progress through the colon, or a less active absorption, or both. The special purpose served by these anastaltic movements obviously is to retard the forward movement and facilitate absorption of water. There would seem to be greater opportunity for a continuance of digestion in the large intestine of the infant therefore than in the adult.

Elliott and Barclay-Smith[113] described a sort of kneading or mixing movement in animals where the sacculi or haustra are well developed, and Schwarz[397] has furnished testimony from his *x*-ray studies that these occur in the human (adult) colon. He states that the changes are strictly local depressions of the contour, now here, now there, suggesting a purely haustral contraction not unlike the rhythmical segmentation discovered by Cannon in the small intestine. If these segmental contractions occur in the infant the effect would be, as in the ascending colon of the adult, to provide a thorough overturning and mixing of the contents thus facilitating as in the small intestine residual digestion and absorption.

The diastaltic or onward movement of the colon and sigmoid do not seem to call for special discussion. The anatomical peculiarity of this region of the infant is the unusual length of the sigmoid flexure. Not infrequently this characteristic of the infant's alimentary tract is so exaggerated as to cause embarrassment in the evacuation of the feces.[230]

Chemical Factors.—Functions of Saliva.—Saliva does not play any very important part in the digestion of the infant. It is secreted in very small amounts during the first week of life[240] but may be stimulated reflexly by chemical means.[404] After the sixth week the amount increases considerably and it is possible, according to Korowin, to collect as much as 1 to 1¼ c.c. in five to seven minutes from a child four months old.

Following the demonstration by Schiffer in 1872 and Korowin in 1874 that a diastatic enzyme is found in the saliva at birth and confirmation of this fact by Keating[222] in 1883, search was made for it in the salivary glands of the fetus of the human and of several other species. It was lacking in the sheep but was found in the fetal calf.[247] Moll[308a] obtained a sufficient amount of saliva from a parotid fistula of a seven-months human fetus to digest starch to sugar (maltose) in five minutes. Ibrahim[213] in fact found diastase in the parotid gland as early as the fourth month and in the submaxillary at the sixth month. There can be no doubt, therefore, that the small amount of saliva secreted by the infant contains an enzyme capable of acting upon starch as soon as it reaches the mouth.[384] Shaw[404] devised a way of collecting the saliva in infants six days to two months of age. Making little sponges of absorbent cotton covered with hospital gauze he introduced these into the infant's mouth and stimulated the secretion by placing a bit of salt on the tongue. Removing the sponge in two or three minutes he washed it with water and secured, after incubation for a few moments, a good sugar reaction in starch solution. Shaw also gave a test meal of barley water to the young infant and, washing it out at various intervals, was able to demonstrate the possibility of action upon starch in the stomach for as long as two hours after feeding. It is well known that pytalin digests starch only to the stage of maltose.[74] Cleavage of this sugar is accomplished by maltase but this enzyme is produced by the salivary gland in the merest traces if at at all.[10]

Variations in the digestive power of the infant's saliva have been studied by Finizio[121] who found the amylolytic action greatest about midday, but to be independent of the presence of starch in the food up to six months of age. Beyond this age there was an increase in diastatic power immediately after a meal of starch. The starch-splitting power of the saliva was tested in several infants every month throughout the first year. It increased steadily from birth to the age of 12 months. At 8 to 10 months it was twice that at birth and at one year a trifle less than that of children two to three years of age. It is to be inferred that an infant one year of age is capable of digesting starch in the stomach, so far as the reaction in that organ will permit, practically as well as two years later. Since ptyalin is a purely diastatic enzyme and there is no starch in the natural food of the newborn it might be inferred that nature had made a mistake in providing an enzyme so long in advance of its need. It will be seen later that the same is true of the pancreatic diastase. This liberal anticipation of future necessity, however, may be regarded as one of the factors of safety in digestion, which man has inherited from remote ancestors, among whom, no doubt, the young began taking fruits and other starchy foods at an earlier stage of infancy.

The reaction of saliva in the adult is alkaline to litmus, but to phenolphthalein and other indicators sensitive to CO_2 it is neutral or slightly acid. According to Munk[315] it behaves like a solution of bicarbonate of soda, or still better perhaps, like an alkaline solution which has been saturated with CO_2. Freshly expectorated saliva, according to the most recent determinations, shows a p_H of 6 to 7.3, but in 80 per cent. of the cases it varies only from 6.6 to 7.1. It may vary in the same person considerably, but such variations show no relation to time of day, or character of the food, and the administration of acid or alkali produces no definite effect.[45]

The reaction of the mouth of the newborn infant, according to Allaria,[8] is neutral or slightly acid to litmus, and in the nursling continues to react acid to litmus but does not turn methyl-orange. The p_H is very slightly on the acid or alkaline side or indeed exactly at the neutral point (7.0) provided freshly secreted saliva is taken. After it remains in the mouth for a while it becomes distinctly acid.

The same author has studied other physico-chemical properties of the infant's saliva[9]. The depression of the freezing point (Δ) is -0.23 to 0.11 degrees with a mean of -0.17 degrees; the electrical conductivity (K) has a mean value of 0.00354 and the chloride content has an average value of 0.04 per cent. It is the poorest in salts of all the body fluids and the total dry residue is only 0.082 per cent.[37] Since it is strongly hypotonic to both the blood and milk, Allaria thinks its significance in digestion is to render the food less hypertonic and because of its neutral reaction to moderate excesses of acid or alkali therein. When milk mixed with saliva is compared with milk alone under the influence of the stomach enzymes[7] the coagulation is delayed to about the same degree as with an equal quantity of distilled water, but the action of pepsin is not hindered at all.

In 1851 Liebig discovered that the salivary glands could be made to discharge their secretions by electrical stimulation of certain definite nerves. Heidenhain later demonstrated that they have two distinct sets of nerve fibers, a sympathetic and a cerebral supply. The cerebral fibers for the submaxillary and sublingual glands traverse the *chorda tympani* branch of the facial; for the parotid they run in the tympanic branch of the glossopharyngeal. The sympathetic fibers for all the glands, according to Langley, make their exit from the spinal cord through the second and fourth or occasionally from the first to fifth thoracic roots and have their cell stations in the superior cervical ganglia or in certain peripheral ganglia situated in the glands themselves. The reflex centers are in the medulla.[237] This center is developed at birth, for as we have seen the flow of saliva in very young infants can be evoked reflexly by chemical means. Clinically it is well known that salivation occurs in babies as young as one month as the result of vagus disturbances. Similarly, in young infants suffering from flatulence or other intestinal disturbances the mouth may become dry as the result of inhibitory nervous impulses playing upon the salivary glands.[117]

In the dog a cerebral center, presumably for psychic control of salivary secretion, has been located in the anterior part of the *gyrus suprasylvius anterior* in front of and below the *sulcus cruciatus.* Stimulation of this region in newborn puppies gives negative results from which Gundobin[165] infers that the scanty secretion of saliva in the newborn infant is due to the imperfect development of the cerebral cortex. At just what age the pleasurable sensation of taking food is developed is very difficult to make out, but there is good reason to suppose it exists by the fourth month when the child exhibits many signs of appreciation of food, and it is presumed that the cortical center is sufficiently developed by this time to be active in the psychic production of saliva. The taste buds, the receptor organs, send up impulses which arouse the cortical cells and these return motor impulses which in turn play upon the reflex centers, thereby lowering the threshold and facilitating the production of saliva. Pfaundler[351] thought he had shown that in the infant, as others have shown for the adult, and as Pavloff especially had demonstrated for the dog, with esophageal fistula, that stomach digestion proceeded more favorably if the food first passed through the mouth. This is known to furnish a psychic element to the gastric glands in the adult; but recent observations do not confirm this for the infant (p. 710).

Secretion and Properties of the Gastric Juice. *Fetal.*—The gastric glands appear in the stomach of the fetus at about five months.[165] They increase greatly in number during the last two months of intra-uterine life. At birth there are as many glands per unit of surface as in the adult,[432] though they are somewhat smaller in size. According to Dudin[106] the reaction of the mucous membrane of the fetal stomach is neutral up to the sixth month after which it is acid. Free HCl was not detected before the ninth month, and it is not always present even at birth.[110] In 55 infants one-half hour to 18 hours of age examined by Hess[187] free HCl was present in all but two.

It has been known for nearly 60 years that the mucous membrane of the fetal stomach would digest albumin. *Pepsin* was found by Langendorff[253] as early as the fourth month and *rennin* by Dudin at the sixth month. The strength of the enzyme naturally varies with the freshness of the material obtained by extraction. *Lipase* was demonstrated by Ibrahim[213] in a glycerin extract of gastric mucosa taken from a fetus of 1,100 gm. weight. The internal secretion *gastrin*, which can be extracted from the pyloric portion of the stomach mucosa and when injected into the circulation has the power to stimulate the gastric glands, as demonstrated by Edkins,[108] has recently been found also in the fetus.

It would appear that these digestive enzymes present in the mammalian stomach long before birth are able to dissolve any albuminous material swallowed with the amniotic fluid; for Preyor[358] found a biuret reaction in the stomach of fetal rabbits which contained also some curds of albuminous material.

Gastric Juice at Birth.—It is evident that a gastric juice containing its characteristic enzymes should be present at birth, and as a fact Hess was able to collect from 8 to 10 c.c. of a highly acid secretion before any food had been given. Carlson[67] has demonstrated that the adult stomach produces a continuous secretion of gastric juice varying from a few cubic centimeters to 60 c.c. per hour independently of any food or of any psychic reaction. The secretion present at birth is doubtless of this character. Carlson attributes the continuous secretion to the action of secretogogues formed from the auto-digestion of mucin and other proteins contained in the gastric juice itself. It is only necessary therefore to account for the primary stimulus to explain its continuous production.

Secretory Mechanism.—The gastric secretion is produced in answer to some stimulus acting upon the gastric glands. Food in the stomach can act chemically by means of secretogogues even after all nervous connections with the stomach are severed (Popielski, Bickel). According to Popielski[353] the secretogogue arouses a reflex from the intrinsic nervous mechanism in the stomach itself. According to Edkins the secretogogue acts upon the pyloric mucosa causing the formation of *gastrin* which then acts upon the gastric glands by way of the circulation. Milk does not furnish very strong chemical stimuli as does, for example, meat.

It was the great merit of Pavloff[346] to discover that the normal stimulation of the gastric glands through the extrinsic nervous system follows two sensory pathways, one from the stomach itself and one from the sense organs (eyes, nose, taste buds) of the head. That secretion poured out in answer to stimuli sent to the sensorium (and association centers) from the sense organs he called the psychic secretion. Whether a true psychic secretion is possible in a newborn or very young mammal is a mooted question. It has been affirmed for the newborn dog by Cohnheim and Soetbeer[76] and for the newborn infant by Pfaundler,[351] Nothmann,[328] and others. It is vigorously denied by Rood Taylor[423] who devised a suction apparatus which enabled him to carry out sham feeding and to recover all of the food from the esophagus before it reached the stomach. In such experiments there was never, in infants from a few hours to five months of age, any increase in gastric secretion as the result of passing the milk through the mouth. Taylor takes the position that previous observers had failed to take account of the continuous secretion which in the fasting infant he calls, after Carlson, the "hunger juice."

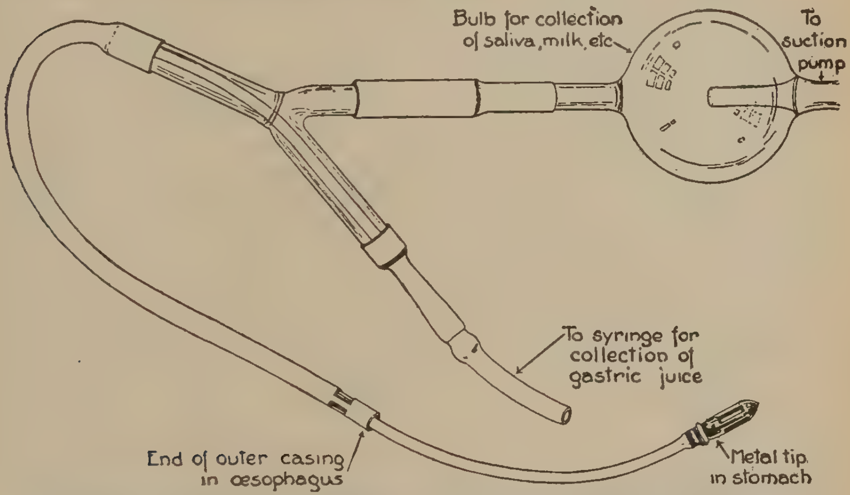
Bulb for collection of saliva, milk, etc.
To suction pump
To syringe for collection of gastric juice
End of outer casing in œsophagus
Metal tip in stomach

FIG. 244.—Apparatus for collecting food from the esophagus (sham-feeding) and gastric juice from the stomach of an infant. (Rood Taylor, Amer. Journ. Dis. of Children, 1917, xiv, p. 260.)

In children above the age of infancy a psychic secretion appears more probable. Bogen[48] made extensive observations on a child three and one-half years old with an absolute closure of the esophagus caused by drinking strong alkali. Sham feeding with meat was given more than forty times accompanied always by a definite tone blown upon a small trumpet. Subsequently when this tone was produced without feeding, the stomach was observed through the fistula to secrete actively on seven out of ten trials. Chewing meat for 15 minutes caused the secretion of 5 to 25 c.c. of juice. The inhibiting influence of pain and anger also were observed. Hornberg[209] made similar observations on a five-year-old boy with the same infirmity. He was not able to induce secretion by the mere sight or smelling of food, probably, as Carlson states, because the child became angry when he was not permitted to eat (chew) the food at once.

Character of the Gastric Juice in Infancy and Childhood.—The hunger and appetite gastric juice in Carlson's[67] adult fistulous subject had an average specific gravity of 1,007, and a molecular lowering of the freezing point of −0.47°C. to −0.62°C. The same values expressing density and the osmotic concentration were found by Sommerfeld[409] in the appetite juice of a 10-year-old girl. The total nitrogen of the appetite juice of the adult man is 0.60 gm. in 100 c.c. (Carlson); the ammonia amounts to 2 or 3 mg. per 100 c.c. Sommerfeld found no ammonia in the pure gastric juice from his fistulous girl. He did not determine the total nitrogen. Formol-titratable (monamino-acid) nitrogen is found in the appetite juice to the extent of 3 to 9 mg. per 100 c.c. It has not been studied in the gastric juice of infants.

In discussing the acidity of the gastric juice it is necessary in the light of the most recent researches[67] to distinguish at least three kinds or classes of this secretion: (*a*) that which is produced continuously and is found at any time when the stomach is empty of food; (*b*) the "hunger juice," differing from the preceding merely by the fact of greater purity and named from the fact of its occurrence in the stomach a longer time after taking food; and (*c*) the appetite juice, or psychic secretion, produced in immediate anticipation of taking food, which is the purest of all. These distinctions are clearly seen in the following table of analyses given by Carlson for a fistulous subject whom he studied for a number of years.

TABLE 47.—ACIDITY OF NORMAL GASTRIC JUICE (CARLSON)

Kind of secretion	Number of observations	Average acidity	
		Free, per cent.	Total, per cent.
Continuous, from empty stomach*	235	0.18	0.23
Hunger juice	180	0.25	0.34
Appetite juice	285	0.40	0.48

*Taken one hour after washing out the stomach with 200 c.c. of water.

There are two factors, according to Carlson, which account for the differences in acidity here shown; one is the rate of secretion, the other is the power of dilution and neutralization. The normal acidity of gastric juice *rapidly* produced is very close to 0.5 per cent. But if it is produced *slowly*, even where no saliva can mix with it as in the fistulous subject, there is opportunity for partial neutralization and dilution by the mucous secretion of the gastric glands and by the alkaline contents of the duodenum regurgitated into the stomach. The latter mechanism for self regulation of the acidity of the gastric contents, first described by Boldyreff,[50] has now been firmly established for the adult.

The continuous secretion therefore is of low acidity primarily because it is secreted slowly; but also because it is diluted and partly neutralized. Hunger juice is of stronger acidity because it is produced more rapidly and may be recovered in quantity before there is time for much dilution and neutralization. Appetite juice is produced so rapidly that it may be recovered pure before there is any dilution or neutralization.

These facts must be borne in mind in estimating the acidity of the gastric juice of infants and children. Hess[187] found gastric juice, free of saliva, in newborn infants immediately after passing the stomach tube, which showed a total acidity of 0.4 per cent. HCl. He emphasized the fact that this secretion is continuously produced; but since he did not wash out the stomach as did Carlson, what he found is probably to be classed rather as hunger juice with which in the adult it more nearly agrees (Table 47). Rood Taylor[423] also found the hunger juice of infants equal in acidity with that of the adult.

It is evident that the gastric glands at birth and probably continuously thereafter are able to secrete gastric juice of full strength. When lower acidities are found in the empty stomach they are due to dilution and partial neutralization. This seems to be accomplished in the infant by the stomach itself or through the agency of saliva and very little if at all through admixture of duodenal contents; for Reiche[360] was unable to find any trypsin in the stomach after feeding cream, and Hess was not able to induce a flow of pancreatic secretion in the newborn by instillation of gastric juice into the duodenum. In the fistulous girl 10 years of age studied by Sommerfeld[409] the appetite juice secreted after sham feeding with different foods showed a variable acidity as follows: After milk, 0.38 per cent.; meat, 0.41 per cent.; bread, 0.47 per cent.; sugar, 0.38 per cent.; mixed food, 0.42 per cent. The chlorine content after mixed food was 0.53 to 0.59 per cent. The total solids amounted to 0.41 to 0.47 per cent. of which 40 to 50 per cent. was mineral matter.

Reaction after Feeding.—After feeding with milk the acidity of the infant's stomach is greatly reduced owing to the binding property of the milk proteins. An hour and a quarter to two hours after feeding at the breast, however, Wohlmann[467] found an acidity of 0.08 to 0.18 per cent., and Allaria[11] observed after feeding with cow's milk that the concentration of chlorides and total acidity increased as the concentration of milk sugar decreased. A part of this total acidity is due to the presence of fatty acids; for Dudin[106] found the free HCl an hour and a quarter after feeding a premature infant 17 days old with cow's milk to be only 0.008 per cent. Sedgwick[398] demonstrated the presence of lipase in the stomachs of newborn rabbits and of infants in the second week and accounted for a considerable part of the acidity as due to fatty acids. Hamburger and Sperck[170] were able to demonstrate free acid more abundantly, the later after breast feeding the contents were taken, but never within one hour. According to these authors the total acidity was almost always greater than the binding power of the original milk, from which they concluded that the binding power of the acid must be increased under the influence of stomach digestion or that the stomach contents become more concentrated by the absorption of substances which could not bind up the acid. Owing to the greater binding power of cow's milk the combined acid may amount to three times as much after artificial feeding as after breast-feeding. Free HCl to the extent of 0.07 to 0.08 per cent. prevents the breakdown of lactose into lactic acid; but with the heavier casein of cow's milk the free HCl may be reduced to such a point that lactic acid is readily produced. Wentworth, using a modified form of Sjöquist's method, recorded acidities in nine well-nourished infants from 18 days to eight months of age one hour after feeding. Out of 12 determinations one showed 0.12 per cent., one 0.09 per cent., nine were between 0.01 and 0.05 and one was as low as 0.005.

Hydrogen-ion Concentration.—The titration method is not a satisfactory way of expressing acidity in the stomach; for (1) the reaction depends upon the indicator used, and (2) in titrating with an alkali there is aconstant shifting of the neutral point until all of the combined as well as the free HCl is completely neutralized.

A more accurate way of expressing free acidity is in terms of the concentration of the hydrogen ion. So far as its influence upon the action of ferments is concerned this is the only acidity that is effective. The p_H of the undiluted appetite juice from a gastric fistula[300] is in the neighborhood of 1.00, or the concentration of hydrogen ions expressed directly is 8.13×10^{-2}. Taylor[423] employing the gas chain apparatus of McClendon found the C_H of the hunger juice in an infant two hours old before nursing to be 0.3×10^{-2}, and in another five months of age seven hours after food 0.5×10^{-1}.

After feeding the acidity of the stomach is rather more constant when expressed by this method than by the titration method. Hahn[167] fed one-third cream and two-thirds milk and at the height of digestion found a fairly constant acidity of $C_H = 1.0 \times 10^{-5}$, which, according to VanDam,[440] is the optimum reaction for the coagulation of milk by rennin and according to Davidsohn[92] is the best also for the action of gastric lipase. Salge[380] confirmed the value of p_H found by Hahn, for infants on an exclusive milk diet, but finds a lower value (higher acidity) in children who were taking other foods. For those who find it laborious to pass from one mode of expressing acidity to the other the following conversion table will be of service:

TABLE 48.—DIFFERENT METHODS OF EXPRESSING THE SAME ACIDITY

HCl normality	C_{H+}	p_H
1.0 N.	8.0×10^{-1}	0.10
0.1 N.	8.4×10^{-2}	1.07
0.01 N.	9.5×10^{-3}	2.02
0.001 N.	9.7×10^{-4}	3.01

The optimum concentration of hydrogen ions for digestion of proteins by pepsin has been found by the gas chain method to be 0.02 to 0.06 N or 2 to 6 $\times$ 10^{-2}. According to Davidsohn the optimum is 1.6 $\times$ 10^{-2}. Working with casein and gastric juice of infants he was not able to demonstrate any appreciable digestion at the acidities found by Hahn and Salge in the infant's stomach at the "height of digestion." McClendon[285] measured the H-ion concentration of 27 different samples of gastric contents taken from infants under one month of age at different intervals after feeding. From these he plotted a curve, using the modes of the variations for each time interval. The curve shows that there is little or no change in the acidity from one-quarter to one hour after nursing, the level being at about 0.000005 N for the H-ions. Within the second hour however it rises to 0.00012, dips down again at the half hour, then rises to 0.001 at the third, and to 0.01 at the fourth hour, which is the level of acidity in the adult stomach after a meal. It was during the first hour after feeding that Hahn and Salge took their samples and for this reason they did not find the higher acidities. By the time the free acidity reaches a level at which pepsin can act rapidly on casein (third or fourth hour according to McClendon) the milk has left the stomach (p. 698, *seq.*). Hence, again the conclusion that protein digestion cannot proceed far in the infant's stomach. However, it should be noted that the relatively high acidity is necessary for the activation of pepsinogen to pepsin and that once this activation occurs slow digestion is possible even at a very low acidity.[410]

Hess[187] determined the acidity upon the stomach contents of breast-fed infants and found that it increases slowly up to nine months at which time it is quite sufficient to activate pepsin. He was impressed with the greater effect of breast milk to stimulate the production of HCl than of meat extract. Kronenberg[246] argued that the albumoses and peptones occur in the chyme as it leaves the stomach in sufficient amount to prove that peptic digestion is of considerable importance notwithstanding the claims of Allaria, Davidsohn and Salge that the acidity is too low. He found the acidity of the stomach at 18 to 20 months of age the same after test meals as in the adult and proved to his satisfaction that digestion of milk with an artificial gastric juice at a C of 1 $\times$ 10^{-4} (indicator) or 0.5 $\times$ 10^{-5} (gas-chain method) can reach significant proportions.

Finizio[123] finds that 100 c.c. of mother's milk binds 0.1168 gm. HCl, but by adding progressively increasing quantities of a normal solution to a mixture of mother's milk and pepsin, digestion may take place before this quantity is bound, *i.e.*, in the absence of free HCl. Naturally the quantity of acid bound will depend upon the quantity of protein present. Heubner[192] gave 0.324 gm. HCl as the amount which is capable of being bound by cow's milk, and approximately one-half this, 0.162 gm., as the amount for mother's milk. As we shall see later the activity of pepsin and rennin may depend altogether upon the reaction of the gastric secretion. Individual variations doubtless must be reckoned with, depending in part upon the emptying time and this in turn upon the anatomical shape of the stomach, and in part upon the activity of the glands.

External Factors.—A recent observation by Goyena and Pettit[157] on the adult may be of significance in connection with kidney inefficiency in the infant. The NaCl content of the blood almost parallels the Cl content of the gastric juice, so that when there is retention of the salt from impermeability of the kidney, the stomach will normally show hyperchlorhydria, *i.e.*, rapid secretion, and this indeed may be the first sign of kidney insufficiency. Czerny and Keller[86] are strongly of the opinion that hyperacidity in the sense of an excessive percentage of acid in the gastric secretion of the infant has never been proved; but in the light of Carlson's work, hyperchlorhydria never means anything more than rapid secretion of a juice of constant acidity. Cohen[73] has recently observed that the secretion of chlorides in the dog is independent of the free acidity of the gastric juice.

Enzymes of the Gastric Juice.—There are three positive enzymes, not to speak of possible anti-enzymes, in the gastric juice all of which are present at birth (p. 710). The one which is thought of as most characteristic of the young mammalian stomach is the one which brings about the coagulation of milk. It would seem important for a thorough understanding of digestion in infancy that a fairly complete account of this enzyme be given.

Rennin or Chymosin.—Curiously enough the active principle which causes coagulation of milk is produced by many other organs than the stomach, *e.g.*, pancreas, liver, lungs, kidneys, and is rather widely distributed in nature, even in the vegetable kingdom. It is found rather abundantly in such fruits as the pawpaw, the fig and tomato and occurs in such unexpected places as in the cabbage, in algæ and fungi. All of these rennins differ among themselves, and those produced by animals differ from those produced by plants. Some coagulate unheated milk better than boiled milk; others the reverse.[109] Rennin produced by a cold-blooded animal like a crab is much more resistant to temperature changes than that produced by a mammal. Those produced by a calf, which is the best known commercially, and by the infant are exceedingly sensitive to temperature. The rapidity of action may be affected by the influence of temperature on the enzyme itself or upon the milk. The reaction of the medium also may determine the effect of temperature upon the coagulation time. With calf's rennin and therefore presumably with infant's rennin as well the temperature to which the milk has been previously heated affects the coagulation time. Effront gives the following table:

TABLE 49.—INFLUENCE OF A PREVIOUS HEATING ON THE COAGULATION OF COW'S MILK BY CALF'S RENNET (EFFRONT)

Previous temperature of the milk, degrees Centigrade	Time for coagulation, minutes
30	21
40	21
50	24
60	26
70	28
80	31
90	41
100	48

In each case the milk was held at the temperature indicated for one hour. It was brought to 40°C. and the same amount of rennin added. We see that boiled milk requires double the time taken to coagulate normal milk. This is due to the precipitation of calcium ions whose strongly accelerating power is well known for coagulating milk as well as blood. However, boiling also threw down the albumins of milk which retard coagulation. With fig rennin the removal of the albumins favors coagulation more than the precipitation of calcium hinders the reaction, so that it acts better on boiled than on unboiled milk. Figs or fig juice with boiled milk might therefore prove advantageous when boiled milk must be used in infant feeding.

Acids up to 0.4 per cent., the normal reaction of hunger juice (p. 713), accelerate the action of rennin. Even in very small amounts acid produces very manifest results. It acts as an excitant to the enzyme itself and at the same time prepares the milk so that it is much more susceptible to the enzyme.

Alkalies, on the other hand, retard the action of rennin even more. A solution of calf's rennet diluted and made up to N/500 with sodium hydroxide losses about 50 per cent. of its activity in 20 minutes. Carbonates are not so destructive as caustic alkali, and bicarbonates have less effect than the normal salt.[273] Lorcher and Duclaux[105] have studied the influence of adding various other salts to milk. They agree that sodium phosphate (Na_2HPO_4) retards coagulation while the corresponding salt of potassium accelerates it. Among the other accelerating salts are barium nitrate, chlorides of barium, calcium, strontium, cadmium and aluminum. In the group of retarding salts are the sulphates, iodides, bromides, chlorides and fluorides of potassium and sodium. Obviously it is the kation rather than the anion which determines the effect.

According to Gerber[150] the explanation of the effect of a given salt (kation) is to be found chiefly in its effect upon the calcium phosphate of the milk. Rennin is known to be strongly calcophile and the neutral salts of sodium and potassium change the medium (milk) rendering it less favorable by precipitation of the calcium. If pains be taken to keep the calcium in solution by using the acid phosphates, for example, small quantities of these salts act as accelerators rather than retarders. The same is true of the acid sulphates up to a certain point of concentration.

Rennin is likewise very sensitive to the action of antiseptics. Formaldehyde in milk to the extent of 1 gm. per liter very considerably retards coagulation and 3 gm. completely suspends the action. Rennin exists in the mucous membrane of the stomach in two different states, the active enzyme and pro-rennin. Under the influence of acid in very small amount at the optimum temperature the pro-enzyme is rapidly transformed into the enzyme. According to Hedin[178] the pro-rennin is combined with an anti-rennin. HCl acts to free the enzyme and at the same time to destroy the anti-rennin.

While some observers have failed to find rennin in the infant's stomach immediately after birth (Raudintz, Van Puteran) this failure, according to Szydlowski,[416] may be due to the fact that the enzyme is so readily adsorbed upon solid food particles that it is lacking from the filtrate. This author found it always present in unfiltered washings taken from the empty stomach, and in a series of 23 children 2 to 14 days of age the stomach contents taken one-fourth to two hours after breast feeding contained in every case sufficient rennin to coagulate cow's milk at body temperature.

The reaction at which milk coagulates most rapidly under the influence of rennin has already been noted (p. 714). It should be mentioned further that there is some difference between cow's milk and human milk in this respect, the latter requiring a slightly higher acidity ($C_H = 1.1 \times 10^{-6}$) than the former (3×10^{-7}).[93] Adding rennin to both kinds of milk and letting them stand until coagulation occurs it is invariably noted that cow's milk sets much sooner than human milk. This difference has been ascribed by Davidsohn to the difference in salt content of the two milks (p. 763).

Nature of Coagulation.—The protein in milk which is acted upon by rennin is known as caseinogen. It is in large part in perfect solution; but in small part is present as a suspension. There are two distinct steps in the process of caseification. One is the transformation in some way of the caseinogen into a different compound (caseogen) under the influence of the enzyme. The other is the precipitation or setting of the clot under the influence of calcium ions. That calcium is necessary is as easily demonstrated as that Ca is necessary to clotting of blood. One has only to treat the milk with a soluble oxalate or with sodium fluoride. That the rennin changes the caseinogen is proved by the fact that an amount of enzyme necessary to clot a given quantity of natural milk in 20 minutes will act instantly, after coagulation has been suspended for 20 minutes by removal of calcium, when a few drops of $CaCl_2$ are added.

According to Arthus[22] caseinogen is split by rennin into two proteins, the caseogen, which he calls *paracasein*, and *lactoproteose*. The calcium ions react only with paracasein forming the true caseum or clot, while the lactoproteose remains in solution. The amount of the proteose however seems to vary with the age of the milk and it is not yet certain that it is not produced by bacteria or by pepsin which always accompanies rennin. Whether the calcium actually unites with the caseogen (paracasein), or is only carried down by the latter when it is separated out, has been much discussed. The known fact is that the caseum always contains calcium; but this fact is equally well explained by the supposition that calcium phosphate precipitates out carrying down with it the caseogen. The nature of the transformation of caseinogen into caseogen also still remains to be explained.

As opposed to this chemical conception of coagulation just outlined is the physical hypothesis of Duclaux according to which coagulation under rennin is very similar to coagulation under the influence of neutral salts of the alkaline earths; *e.g.*, $CaCl_2$, $SrCl_2$. $BaCl_2$, $Ba(NO_3)_2$. Here it is fairly clear, the substance in solution (caseinogen) merely changes its state under the influence of the added salt. Both caseinogen and the calcium phosphate being partly in solution and partly in suspension, the stability of the two is interdependent, each exerting a reciprocal influence on the other. By addition of an alkaline-earth salt coagulation is brought about because the equilibrium which existed between the caseinogen and the various inorganic substances contained in the milk is disturbed.

Likewise the action of rennin can be explained by the modification caused in the structure of the caseinogen. Rennin changes it into casein which is more sensitive toward the inorganic constituents and hence is precipitated. In oxalated milk the casein remains in suspension, but owing to the sensitizing influence of rennin an amount of $CaCl_2$ or NaCl will now cause coagulation which without the rennin would have had no effect. Becoming insoluble the casein carries down with it the calcium phosphate, but the resulting caseum is rather a mixture than a true compound of organic and inorganic constituents.

Pepsin.—This enzyme was first isolated by Wasmann in 1839, although its name had been given earlier by Schwann. It is the really significant active principle of gastric juice, but is found associated with other proteolytic enzymes in the digestive glands of some animals, is encountered in other tissues, notably the blood and muscles, and occurs frequently in plants.

Purified preparations of pepsin with high enzymic power give an analysis of approximately the same composition as white of egg.[348] Pepsin however cannot be obtained free of mineral matter. Chlorine is always present; and although the ash can be reduced to 0.1 per cent., iron can always be detected as a constituent. This mineral matter is not to be regarded as an impurity; for according to Bertrand oxidases are true combinations of manganese with proteolytic substances, and according to Lisbonne pancreatic, salivary and vegetable amylases when completely free from inorganic substances will not act upon starch.[109] It is not improbable that iron will be found to represent an indispensable element for active pepsin. Pepsin, in common with some other enzymes, is quite readily adsorbed by proteins.[3] This property plays an important part in the digestion of proteins, particularly of those contained in connective tissue. Other proteins like the casein of milk, after separation by coagulation, can adsorb pepsin and carry it into the intestine, where its action may continue for some time owing to the protection against the alkaline medium afforded by its physical combination with the protein. Michaelis[305] finds that the capacity of any enzyme to be adsorbed depends upon the nature of the medium and the chemical nature of the enzyme itself. Pepsin, for example, is thrown down by a precipitation of calcium phosphate, produced in the same medium with a slightly acid reaction; while trypsin is not so precipitated. This particular reaction, which it will be remembered also interferes with the action of rennin because of its predilection for calcium, is therefore especially to be avoided in the stomach of the infant.

Pepsin acts best, as we have seen (p. 715), at an acidity of 0.02 to 0.06N. The exact acidity however varies with the nature of the protein acted upon [350] and the purity of the enzyme, a pepsin of little activity requiring a larger quantity of acid than the pepsin of good quality.[238]

The hydrochloric acid of the stomach enters into a real chemical union with the protein to be attacked by pepsin. The protein is thereby rendered less stable and the action of pepsin is favored. The amount of acid combined depends upon the molecular weight, or chemical complexity of the protein molecule; thus:

1 albumin molecule combines 4 mols. HCl
1 albumose molecule combines 3 mols. HCl
1 peptone molecule combines 2 mols. HCl

Since pepsin acts only upon the acid-protein combination it is evident that the amount of acid required will depend upon the amount necessary for neutralization. Just as the ptyalin of saliva is protected from the acid reaction of the stomach by penetration into the food in the process of mastication, so the pepsin is protected from the alkaline reaction of the intestine not only by adsorption on the surface of the protein, but also by penetration into the mass of the food. Abderhalden has found active pepsin throughout the small intestine of the dog.

It is generally conceded that pepsin as it exists in the mucous membrane is not yet ready to act upon protein, and this preliminary state is called pepsinogen. According to one view pepsinogen is activated by being transformed under the influence of acid into pepsin. According to another the preliminary state is pepsin, but it is fixed to the mucous membrane by a sort of molecular adhesion. In accordance with this view acid is said to act merely to release the pepsin and pass it into solution.

The occurrence of pepsin in the gastric mucosa of the stillborn infant was proved long since by Zweifel and by Hammersten. Later observers have experienced no difficulty in obtaining evidence of its action in newborn and older infants provided sufficient acid (p. 715) was present.

Peptones are easily demonstrated after giving milk but their presence might be due to bacteria or, conceivably, they might represent an early cleavage product in the process of coagulation (p. 718). Gastric juice drawn by stomach tube the first few hours after birth has recently been shown[187] to contain both pepsin and hydrochloric acid in sufficient concentration to digest fibrin. Stomach contents withdrawn soon after a meal of milk may not show any peptic activity,[431] for the reason that the free acid has all been tied up by the milk proteins. Withdrawn at a later stage of digestion peptic activity may be exhibited without addition of acid. Ramsey[359] concludes, from an extensive study of the subject, that in general it must be conceded that gastric juice in the infant is not lacking in pepsin, that in the normal infant it is capable of transforming protein into peptone without the addition of acid, and that while pepsin may occur at times as in the adult without acid, it is readily activated either with lactic acid or hydrochloric. Practically, as Davidsohn[92] points out, lactic acid alone could scarcely ever suffice to replace HCl in the infant's stomach for a concentration of 0.9 per cent. would be required to produce a reaction of $C_H = 1 \times 10^{-3}$, whereas, as Heubner has shown, it rarely reaches a concentration of more than 0.1 or 0.2 per cent.

Are Rennin and Pepsin Identical?—This is a question of considerable theoretic interest which may at any moment become of practical importance. In favor of identity is the undisputed fact that the two enzymes invariably occur together in nature, and the further observation, not yet quite conclusively established as a fact, that an antirennin produced by immunization acts both upon rennin and pepsin. If the two properties of coagulation and digestion are in truth properties of one and the same substance, this substance can only exhibit its two phases under quite different conditions. Thus coagulation takes place in a neutral medium and peptonization only in an acid medium. In spite of this some investigators go so far as to say that the two properties are always exhibited in parallel strengths in different samples or kinds of gastric juice. Michaelis[306] made the interesting suggestion that pepsin behaves as an anion in weakly acid solutions ($C_H = 0.001$) and as a kation in stronger acids. As anion he thinks pepsin has the power of coagulation, *i.e.*, anodic pepsin is rennin; while at higher acidities ($C_H = 0.02$ to 0.06) the same substance is kathodic and has the digestive action of pepsin.

Proponents of the unitary theory cannot see any reason for admitting the existence of an enzyme like rennin (associated with pepsin), in plant juices for example, where it cannot perform any useful function. In answer to this line of reasoning it has been argued that the rennin may provide for condensation or synthesis of proteolytic products set free by the pepsin; and in point of fact Danilewsky[90] has demonstrated that rennin can under certain circumstances perform this very service. In such a case it would appear to be a sort of reversed pepsin.

The material formed by the Danilewsky reaction (rennin acting upon peptones) has been called *plasteïn*, and it is known from analysis of the plasteïn produced from Witte's peptone[263] that the synthesized product is a very complex substance, approaching the albumins themselves in composition. If rennin were to play this role in the digestion of infancy the resulting product might be looked upon as a reserve protein different from that from which it was formed, and capable of entering into the circulation without the intervention of another enzyme, by a slight change in reaction of the medium.

It turns out on closer examination that rennin and pepsin in different extracts of gastric mucosa often are not present in equal strength. Thus in the gastric mucosæ of the hog and the calf the following data are obtained.[109]

	Digesting power	Coagulating power
Hog	1	1
Calf	1	9

Moreover the two enzymes can be separated by chemical means. Starting with a maceration of hog's mucous membrane made in 5 per cent. NaCl a fairly pure solution of pepsin is obtained. Saturating with NaCl causes a precipitation, composed chiefly of rennin, which may be eliminated in this manner. Dialysing the filtered liquid to remove the excess of NaCl, pepsin may then be precipitated by ammonium sulphate. Redissolving in water, dialyzing against 0.2 per cent. HCl a solution rich in pepsin but containing only traces of rennin is obtained.

It appears from this brief discussion that the weight of evidence is in favor of the view that rennin and pepsin are distinct and separate enzymes. The discovery of one of them wholly independent of the other, or the preparation of an anti-rennin or an anti-pepsin which would act specifically, will be necessary to place the matter beyond all doubt.

Stomach Lipase.—This third enzyme of the infant's stomach has been demonstrated by Sedgwick.[399] Under ordinary circumstances when lipase is found in the stomach it is accounted for by regurgitation of duodenal contents (p. 712), and the well-known methods of Volhard of securing duodenal fluid by introduction of oil into the empty stomach is predicated upon this mechanism. Probably even in the infant too occurence of pancreatic lipase in the stomach is not infrequent. But Ibrahim[213] maintains that regurgitation cannot be induced by the Volhard method, and both Sedgwick and Ibrahim found indubitable evidence of lipolytic activity in extracts made from the gastric mucosa taken at or near birth, under circumstances which precluded admixture of the pancreatic secretion.*

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* The failure of other authors to obtain satisfactory evidence that lipase is produced by the stomach cannot be explained in every case. Engel's[115] negative results on an infant with pyloric stenosis and a high jejunostomy, so that stomach

Gastric lipase, it appears, has somewhat different properties from pancreatic lipase. It acts vigorously only upon emulsified fat like the fat of milk, and it prefers a more acid medium. The optimal reaction with pancreatic lipase of the infant obtained by means of the duodenal sound of Hess, according to Davidsohn,[92] was $C_H = 3.2 \times 10^{-9}$ or $p_H = 8.5$; while lipase obtained from the stomach contents withdrawn three-quarters of an hour after a meal of 100 gm. barley gruel acted most vigorously on tributyrin at $C_H = 10^{-4}$ or 10^{-5} or $p_H = 4$ or 5.

Sedgwick estimates that 25 per cent. of the fat of milk may be split by the stomach lipase.

Summary of Gastric Digestion in the Infant.—We are now in position to recapitulate briefly the events of digestion in the stomach of the infant. Milk mixed with more or less saliva enters the stomach. The degree of dilution (of cow's milk) previous to feeding or by admixture of saliva will determine the character of the clot formed. Cow's milk coagulates more rapidly and firmly even after modification than does mother's milk. This is due in part to the greater proportion of albumin to casein in mother's milk and in part to the more favorable salt content of cow's milk.

HCl of the gastric juice is bound by the casein more rapidly before it is thrown down than afterward, hence other things equal, more HCl will be bound by mother's milk than by cow's milk. Saliva appears to favor the penetration of the clot by hydrochloric acid and the consequent formation of acid-albuminate.[7]

Interesting observations have been reported by Gaucher[148] on the adaptation of gastric juice to the kind of food taken. Artificially fed infants produced more gastric juice in proportion to the amount of milk taken than did breast-fed infants. The stomach contents evacuated one-fourth hour after feeding showed important differences as regards their ability to coagulate milk. That from breast-fed infants coagulated woman's milk instantly and at 37 degrees digested the casein in two hours. On cow's milk it acted much more slowly, coagulating in 30 minutes and requiring several hours for digestion. Contents from artificially fed infants coagulated cow's milk in two to three minutes but required 20 to 30 minutes to coagulate woman's milk.

Slow coagulation is much more favorable to digestion than rapid, because on the one hand the clot is looser, thereby permitting better penetration of the gastric juice, and on the other the whey is expressed more slowly and thus interferes less, either on account of salt content or fluid, with the digestive juices. Digestion of protein in the stomach does not ordinarily proceed farther than the albumose or peptone

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contents should have been readily available, may be due to the fact that he preserved the contents with toluol and may thereby have destroyed the enzyme which is known to be very sensitive to this reagent. The negative results of Rietschel[365 a] in his experiments on the young pig, and by London and his collaborators with fistulous dogs, may be due to physiological peculiarities of these species.

stage. In fact as we have seen, milk often goes directly into the intestine without stopping in the stomach. E. Hess[191] alludes to the fact that in the nursing infant it is the early milk from the breast running low in fat (1.0 per cent.) which thus passes by the stomach unchanged, but that the later milk, running up to 6 or 7 per cent. fat, is arrested by the stomach.

The importance of inorganic constituents of the milk in digestion may be illustrated by the following facts: Stomach lipase works much better in human milk whey than in cow's milk whey. Adding tributyrin to whey which had been heated previously to destroy the ferments native in milk and supplying lipase from the pure gastric juice of the infant, Davidsohn[93] found that digestion went on rapidly in human whey but scarcely progressed at all in cow's whey. The explanation is found in the composition of the salts present. The following table gives the concentration of the principal kations and anions in (1) mother's milk and (2) cow's milk diluted 5.84 times, after Friedenthal.[139]

CONCENTRATION OF IONS IN:

WHOLE MOTHER'S MILK	AND	COW'S MILK × 5.84
$K^{+} = 8.9 \times 10^{-3}$		$K^{+} = 6.5 \times 10^{-3}$
$Na^{+} = 5.8 \times 10^{-3}$		$Na^{+} = 5.5 \times 10^{-3}$
$Mg^{\ddagger} = 1.8 \times 10^{-3}$		$Mg^{\ddagger} = 1.8 \times 10^{-3}$
$Ca^{\ddagger} = 5.09 \times 10^{-3}$		$Ca^{\ddagger} = 5.09 \times 10^{-3}$
$Cl^{-} = 12.4 \times 10^{-3}$		$Cl^{-} = 6.6 \times 10^{-3}$
$PO_4^{\equiv} = 2.7 \times 10^{-3}$		$PO_4^{\equiv} = 2.3 \times 10^{-3}$
$\text{Rest } Ci^{\equiv} = 2.7 \times 10^{-3}$		$\text{Rest } Ci^{\equiv} = 4.2 \times 10^{-3}$

Making calcium and magnesium equal in the two milks as can be done by this dilution of cow's milk leaves it plainly deficient in potassium, sodium, chlorine and phosphate and still redundant in the citrate residue. In short, according to this author, there is no simple dilution which will make cow's milk the equivalent of mother's milk in all the inorganic constituents. It may be supposed that when milk salt supplements are added, as Friedenthal recommends, the lipolytic activity would be the same in the two milks. It should be borne in mind that human milk itself contains an active lipase* and with the stomach lipase a very lively lipolysis may take place in breast feeding, so that one-quarter or more of the entire fat of the milk may be split up before the food leaves the stomach. The fatty acids set free, according to Sedgwick, may contribute very materially to the total acidity of the stomach.

In spite of this high total acidity, however, the hydrogen-ion concentration of the infant's stomach is not high enough to furnish the best medium for pepsin until the stomach is nearly empty. At one hour after feeding the highest C_H found in one series[91] was 3.9×10^{-6}. At two hours 5.6×10^{-5}. The lowest C_H at which pepsin exercises its gelatinizing effect upon protein is 1.4×10^{-3}.

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*Davidsohn[94] has based a differential test for human milk on this property. Adding a drop or two of tributyrin to 5 or 10 c.c. of the suspected milk in a test tube and holding the tube in the hand for a few moments for warmth, if it is unheated human milk a distinct odor of butyric acid will be detected upon shaking.

Lactose and the inorganic constituents of milk are the first to become available for absorption; for they are free to pass out of the stomach in the whey if they have not already reached the intestine in the unchanged milk. When the stomach has changed the milk as much as it is capable of doing, it passes on to the intestine the following products: Casein and albumin unchanged, caseinate and albuminate, albumoses and peptones; fat unchanged, fatty acids and glycerin, some calcium soaps (?); lactose; inorganic salts.

The digestive fluid which meets these products as they issue from the stomach is a mixture from at least three distinct secretory structures; namely, the pancreas, the intestinal mucosa and the liver. It is possible that a distinction should be made also between the glands of Brunner which in man are found only in the superior division[451] of the duodenum, *i.e.* , above the point of entrance of the hepatic and pancreatic ducts, and the crypts of Lieberkühn. These secretions act simultaneously upon the chyme, but it will be necessary to describe their effects separately.

Secretion and Properties of the Pancreatic Juice.—The secretion of the pancreas collected from a clean fistula is a clear, opalescent fluid whose composition both in concentration of active ferments and in the ash constituents varies with the time of secretion, just as the composition of mammary secretion varies with the condition of the gland at time of milking. In fact the composition of any secretion depends upon the state of recovery from previous action of the gland in question, at the time the product is obtained.

Pancreatic juice freshly drawn is always alkaline with sodium carbonate. In the dog the alkalinity very nearly balances the acidity of the gastric juice and in terms of Na amounts to about 0.3 per cent. Pure appetite gastric juice however, as we have seen (p. 712), contains practically 0.5 per cent. HCl and it has been shown recently by McClendon[284] that the intestinal contents of the dog are normally acid in the upper part, becoming actually alkaline only near the cecum. The reaction seems to depend upon the rapidity with which CO_2, set free by interaction of the HCl of the gastric juice and the Na_2CO_3 of the duodenal fluid, is absorbed. The ultimate cleavage products of proteins (amino-acids) and fats (fatty acids) and any products of fermentation of carbohydrates would contribute to the acidity of the contents, but according to McClendon[287a] and his coworkers all these are absorbed so rapidly that they scarcely have time to affect the reaction. The slight tendency toward acid reaction through the greater part of the intestine therefore is probably due merely to the fact that the secretion of acid by the stomach is not quite balanced by the secretion of alkali by the intestine and accessory structures. The binding of this alkali and its absorption as soap would likewise contribute to the acidity.

The pancreatic enzymes are present in that organ some months before birth.[213] There are at least four of these enzymes: trypsin (trypsinogen), pancreatic lipase (steapsin), amylase (amylopsin), and maltase. Pancreatic juice also coagulates milk, but whether this reaction is due to a separate enzyme turns upon considerations similar to those which apply in the case of gastric rennin (p. 721). Some observers have described lactase as a constituent of pancreatic juice, but the best authorities[411] on pancreatic secretion deny it a place.

All of these enzymes, it might be expected, would be present at birth, and the careful research of A. F. Hess[185] upon duodenal contents obtained by means of the doudenal catheter have justified this expectation. In this study a number of newborn infants were examined before they were put to the breast. Duodenal contents formed without the stimulus of food to incite secretion were obtained in sufficient quantity to test for at least one enzyme in each case. The three main enzymes were found. In older infants a month or more of age sufficient contents could be obtained to test for all three of the enzymes. Amylase was found in increasing amount the older the infant, even though no starch had been fed.

Secretory Mechanism of the Pancreas.—Pancreatic juice is produced in answer to the stimulus of the acid gastric contents acting upon the duodenal mucosa. It can be produced however, as Pawlow showed, by stimulation of the cut vagus after the cardiac inhibitory fibers have had time to degenerate, and at times by stimulation of the splanchnics. Just as in the stomach, a secretion may be called forth from the pancreas by stimulation of the intestinal wall after all nervous connections therewith have been severed.[353] Through the well-known work of Bayliss and Starling[32] it turns out that this effect is produced by way of the blood through the agency of a special substance, which they named *secretin,* dissolved from the mucous membrane of the intestine by the acid. Many kinds of acid, both organic and inorganic, strong enough to effect the solution of prosecretin and change it to secretin are able to mediate the action, and the effect is proportional up to a certain point to the H-ion concentration. A matter of some importance in the feeding of infants is the fact brought out by Popielski[354] that when protein of the food (milk) ties up the acid of the gastric juice to a considerable extent the effectiveness of the stimulus for the production of pancreatic juice is thereby reduced. An illustration is the complete binding of an n/10 sol. of HCl by a 12.5 per cent. solution of Witte's peptone so that no free ions could be demonstrated with tropeölin, Congo red or diamidoazobenzol. However, the acid was not in this case rendered wholly ineffective as a pancreatic stimulus, for the material binding it, according to Popielski, is itself a pancreatic sitmulant. Moreover, amino-acids acting purely by their acidity may augment the secretion,[142] and both lactose and sucrose appear to enhance the effectiveness of acid.[141] Injection of neutral oil into the intestine likewise calls out a flow of pancreatic juice, but the exact mechanism of this reaction is not understood. The unchanged fat of milk would thus reinforce the stimulating effect of all the acid bodies contained in the chyme. It should be emphasized that the production of pancreatic juice in its quantitative relations is regulated by a mechanism which works in the interest of the acid-base balance both in the intestinal tract and in the blood. Secretin produced by acid is carried by the blood stream to the pancreas and excites the production of an alkaline secretion. But as soon as enough alkali has been received in the intestine to neutralize the acid not already bound by protein the production of secretin stops. More acid from the stomach produces more secretin and so on. It may be inferred that excessive acid will produce excessive stimulation of the pancreas, but this is not likely to happen in the infant because of the binding property of the milk proteins.

Alkali in the stomach suppresses the secretion of pancreatic juice by removal of its natural stimulus. Alkali placed directly in the duodenum does the same. But alkali injected into the blood stream, it appears, increases[169] the secretion of pancreatic juice, those basic elements which are difficultly soluble, like calcium, having a much more prolonged effect than the more soluble bases, like sodium and potassium. The action of calcium may be explained by the observation of Hustin[211] that an excised, surviving pancreas will produce its external secretion only when it is perfused with secretin added to blood and that this combination is without effect if the calcium of the blood is first precipitated with oxalate. Extra calcium either prepares the gland for the action of secretin, or has an extraordinary activating effect upon the secretin already present.

Qualitative and *Quantitative Effects of Food.*—Several members of the Pavloff school, notably Walther[457] and Wassilieff,[458] have claimed a qualitative effect of food upon the pancreatic secretion, a diet rich in carbohydrate producing a juice having a more abundant or a more active amylase and a fatty diet producing more lipase or at least a more active lipolysis in the current product. This claim as it relates to animals, chiefly the dog, has not been sustained by later work; and Hess[185] has observed that infants fed on skimmed milk may have in the duodenal juice a lipase of greater activity than others fed on 2 or 3 per cent. fat. Nor was he able to find any parallelism between the protein or starch of the food and the respective amounts of trypsin and amylase in the duodenal fluid. Hess points out that according to the Pavloff's[346] teaching an infant fed exclusively on milk should have no amylase in the pancreas, whereas the fact, it is well known, is quite otherwise. While it may be objected that the method employed by Hess is not at all comparable with the technique employed with dogs, where a fistula is made directly into the pancreatic duct, thus rendering possible observations upon the amount of secretion produced by different foods, as well as qualitative observations upon the pancreatic juice alone, the rejoinder obviously would be that any regulating mechanism which did not produce qualitative effects in the mixed duodenal fluid would be of small consequence in digestion.

It must be remembered that most of the information we now have regarding the pancreatic juice has been gained from animals with artificial fistulæ. Very rarely has opportunity offered of securing unmixed pancreatic juice in man, and never, so far as known to the writer, in the infant. Until the duodenal catheter was introduced by Einhorn, Gross, Rehfuss and others and adapted to the infant by Hess the only recourse for studying pancreatic efficiency was the search for enzymes in the stools. Uncorroborated, this method was and is very unsatisfactory; for many factors intervene between the entrance of the enzyme upon the scene of action and its exit, any one of which might render the results quite worthless. It happens that one series of observations upon the stools of infants with various types of digestive disturbances[168] has given results essentially the same as those obtained by Hess[186] by means of the direct examination of duodenal contents; namely, that in neither acute nor chronic disturbance is there failure of any pancreatic enzyme, save lipase, and this deficiency occurs only in acute intestinal intoxication. The duodenal examination, needless to say, is the more convincing.

Enzymes of the Pancreatic Juice. *Trypsin.*—This most energetic of the digestive enzymes was first definitely isolated from the other enzymes of the pancreatic secretion by Danilewsky[89] in 1862; but its chemical differentiation from pepsin and its name are due to Kühne.[248] In general this difference consists only: (1) in the greater rapidity and more deep-seated cleavage of the protein molecule; and (2) in the lower H-ion concentration at which its best work is done. The early stages of tryptic action are said to be best accomplished in a slightly alkaline medium, but the later stages at a reaction which is nearly neutral. Thus Fernbach and Schoen[118] working with fibrin and employing mono- and di-potassium phosphates for controlling the reaction found that under the influence of the di-potassium salt which is alkaline to methyl orange a greater dissolving action was obtained; but under the mono-salt, which is neutral to the same indicator, the percentage of protein reaching the amino-acid stage was greater.

The optimum reaction for the cleavage of casein by trypsin is not exactly the same as the optimum reaction for fibrin. On the latter it acts most energetically between $C_H = 10^{-8}$ and 5×10^{-9}, while upon casein it produced the greatest effect between 3×10^{-6} and 5×10^{-7}.[254] Since there is great reason to believe that trypsin unites with the protein upon which it acts, it has been suggested that the preliminary union of protein and enzyme is sensitive to the reaction rather than the integrity of the enzyme itself.

It is well known that pancreatic juice drawn from the duct itself does not as a rule contain an active trypsin, and that another enzyme, *enterokinase*, secreted by the intestinal mucosa constitutes, ordinarily, the activating agency. Enterokinase is present at birth and has been traced back in fetal life to the age of six months.[213] Trypsinogen can be changed to trypsin, however, by a variety of substances. Enterokinase is produced by leucocytes and lymphatic glands as well as by intestinal epithelium. It is found in the venom of serpents, in mushrooms and in bacteria. An inactive pancreatic juice inoculated with *Bacillus mensentericus* or *B. subtilis* very quickly acquires a marked proteolytic activity. Finally, of the organic sources milk has been found to contain a substance, very similar to enterokinase and called *lactokinase*,[210] which can activate trypsinogen. Whether this activator is present in milk after it has been mixed with gastric juice or coagulated by rennin is not known.

It is a curious fact that trypsinogen can be activated also by mineral salts, the most effective of which is calcium chloride. This reaction has been studied exhaustively by Delezenne[96] and by Zunz[472] and many details have been learned, but the mechanism of the action is not fully understood. According to Mellanby and Wooley,[295] the calcium effect is due merely to the development of a suitable H-ion concentration for the enterokinase which is already present in the pancreatic juice. However this may be, it is worthy of note that calcium is present in sufficient concentration in milk, even in mother's milk, to be of some effect should this form of activation ever be necessary in tryptic digestion.

The digestion of protein by trypsin is rapid compared with peptic digestion, and amino-acids may be found under favorable circumstances within an hour even *in vitro*. The proteins of mother's milk as well as of cow's milk are completely disintegrated in the intestine of the infant, none of it so far as known being normally absorbed in the form of anything else than amino-acids.

When a protein like casein or lactalbumin is subjected for a long time (*e.g.*, a month) to tryptic digestion *in vitro*, the digest examined from time to time will disclose an *irregular progress* from split-products of high molecular weight to those of low molecular weight. For example, peptones may be abundant early, proceed to a maximum in a few days only to fall off later to a smaller percentage and to rise once more to a second maximum. In other words, there are oscillations in the formation of peptones instead of a regular linear progression, as under peptic digestion. The explanation is that peptones and even albumoses after once being broken down may be reformed by synthesis of smaller proteolytic cleavage products. Such resynthesis of higher proteins may often be signalized by the appearance of a turbidity which itself fluctuates in intensity and finally disappears as the proteoclastic reaction gains the upper hand. This reversibility of enzyme action is a most important property upon which the formation of new tissue proteins and the consequent growth of the child depend (p. 789).

Amylase (*Amylopsin*).—This enzyme was found by Ibrahim in the pancreas of the fetus at six months and by Moro[310] in the pancreas of the newborn child. As already noted, it was identified by A. F. Hess in the duodenal juice of the infant a few hours after birth and before any food had been given. It has recently been found in the meconium,[157a] though in limited concentration. According to both Moro and Hess there is a rapid increase in the amylolytic power of the pancreatic diastase during the first week of life and at one month, as Jacobi and Heubner held, the infant is capable of handling perfectly a small quantity of starch (1 per cent.). Cohnheim[77] has suggested that since enzymes are known to be reversible, perhaps in the fetus the pancreatic diastase may have something to do with the formation of glycogen. This may be its significance also in the newborn. Pancreatic amylase splits starch more rapidly than does ptyalin. Naturally the speed of hydrolysis will depend upon the preparation of the starch by cooking; but the pancreatic enzyme is capable of attacking even uncooked starch[259] and of reducing it to maltose if the amount is not so great as to be overwhelming. Digestion runs exactly the same course under pancreatic amylase as under ptyalin, the only difference being one of speed. The intermediate stages whether of cooked or uncooked starch are: Erythro-dextrin, achröo-dextrin, maltose. Pancreatic juice supplies an additional enzyme maltase to complete the conversion to glucose.

Pozerki[356] has observed that the amylolytic power of pancreatic juice diminishes rapidly in the presence of active trypsin, although it is preserved at full intensity so long as the juice has not been activated. Calcium chloride activation as well as the more usual kinase activation has the same effect. Singularly enough, however, a juice which is actively digesting a protein retains its full amylolytic power and it has been shown by Terroine and Weill[425] that this activation of amylase is due to the presence of amino-acids, especially to glycin, alanin, valin, leucin, phenylalanin, tyrosin, aspartic acid, arginin, histidin and others. It appears from this list that the mono- and di-carboxylic acids and the mono- and di-amino-acids all are effective. The original observation of Keller that the presence of carbohydrate facilitates the digestion of protein can therefore be completed by the converse statement that the presence of proteolytic products facilitates the digestion of starch. In other words the advantage seems to be reciprocal. A very slight concentration of amino-acids—*e.g.*, $1/50{,}000$ to $1/100{,}000$ of glycin—seems to be sufficient and a concentration of $1/10{,}000$ produces a rate of saccharification 30 to 40 times as great as the pancreatic juice alone. But this is not all. Pancreatic amylase can be activated also by saliva in which the ptyalin has been destroyed by the gastric juice or by neutralized gastric juice in which no saliva is present.[370] In either case the effect may be due to amino acids formed by the action of trypsin upon the proteins (pepsin) of gastric juice. These facts only reinforce the conviction which has grown with the progress of science in this field; namely, that the interdependence of the digestive glands is of profound importance. Even the small amount of saliva produced by the new-born plays a useful part in the coagulation of milk in the stomach. When starch is fed it would seem from what has just been said to be particularly important that it be mixed well with saliva not merely for the sake of the small amount of digestion under the influence of ptyalin which it will undergo in the stomach, but also for the activation of amylase in the intestine. It is an old idea in physiology, but one which may have its usefulness even in infant feeding, that only as much starch should be eaten as the subject can thoroughly insalivate. Naturally in the nursling this amount will always be very small.[125]

Lipase (*Steapsin*).—This enzyme which has been found in the pancreas of "fairly young fetuses" and in the duodenal fluid at birth has the same properties as gastric lipase except that it hydrolyzes fat more rapidly in a slightly alkaline or neutral medium (p. 723). Like pancreatic amylase it seems to be very sensitive to the presence of active trypsin—which probably means that as a protein it is digested and destroyed by trypsin.[165] If other proteins are present upon which trypsin can exert its full activity lipase is not destroyed, but like amylase is rendered more active by the products of proteolysis. The action of pancreatic lipase like that of gastric lipase is greater in the whey of human milk than in that of cow's milk.[93]

Adding bile to pancreatic juice increases its lipolytic activity three or fourfold.[322] This is believed to be due to an activating substance which rapidly transforms the zymogen stage, steapsinogen, into the effective lipase. Unlike trypsin, however, a certain amount of the active steapsin exists in the perfectly fresh juice or in pancreatic extract. As between the lipase of the stomach and that of the pancreas the former is relatively more important in infancy and the latter in older children and adults; for the fat of milk is already emulsified while the fat of solid food is not emulsified until it reaches the intestine.

Maltase.—Ibrahim reports maltase but no other inverting enzyme as present in the pancreas of infants dying soon after birth. Its only function is to split maltose, a disaccharide resulting from the digestion of starch, into two molecules of glucose the sugar of the blood. It can be of no significance until starch becomes a component of the diet.

Nuclease.—This name was originated by Iwanoff[214] for an enzyme capable of splitting and dissolving a nuclein. These bodies set free from nucleo-proteins by pepsin, it is claimed[436] are precipitated by the acid reaction of the stomach, but are attacked by the alkaline pancreatic juice and are soon resolved into their component parts, protein (thence peptones etc.) and nucleic acid. Schittenhelm found that pancreatic juice could split thymo-nuclein into a protein and thymonucleic acid which latter became non-gelatinizing, soluble and diffusible. Purin bases also appeared; but according to Kutscher[250] these may be due to self digestion of the pancreatic juice. Purin bases may be demonstrated after acid hydrolysis of the colonic contents in milk-fed infants but the exact source of the nuclein from which they are produced is not known.

The casein of milk is in reality a para-nucleo-protein or nucleo-albumin. It is split by pepsin or trypsin into albumin and a para-nuclein which differs from an ordinary nuclein by the fact that it yields on hydrolysis only phosphoric acid and albumin, but never purin bases. It has never been proved that hydrolysis proceeds so far as to yield free phosphoric acid in the intestine of the infant. Indeed it is believed that the para-nucleic acid is absorbed as such and constitutes an important building stone for synthesis of new body proteins (p. 789).

Intestinal Juice.—The intestine is the real seat of digestion. What takes place in the stomach is largely preliminary. Moreover, it is reserved for the wall of the intestine itself to produce the enzymes which complete the processes of digestion. Notably of this class are maltase which completes the digestion of starch to monosaccharide, and erepsin which attacks the peptones and polypeptids left by the action of trypsin. Of the same order with maltase are *invertase* which splits cane sugar into glucose and fructose, and *lactase* which splits milk sugar into glucose and galactose. A trace of amylase which may be found along with maltase in the secretion of an isolated loop, and enterokinase, which has been discussed on p. 728, complete the list.

It is interesting to note that normal intestinal juice differs in its content of enzymes from a maceration juice made from the mucous membrane. In the former are found enterokinase, erepsin, amylase and maltase; in the latter invertase and lactase, in addition to the other four.

Secretory Mechanism.—Secretory fibers for the duodenum have never been found in the vagus, although a "paralytic secretion"[296] is produced in a quite similar manner to the corresponding phenomenon in the salivary glands when all the nerves supplying a segment of the intestine are severed. The mucous membrane responds to mechanical stimulation,[381] but chemical stimulants (secretogogues) are much more efficacious. According to Frouin[140] the hydrochloric acid of the stomach, soaps, ether and chloral produce active secretion both in the same segment (Thiry fistula) and in non-adjacent segments not directly touched by the reagent. It is probable that some sort of secretin is involved in this reaction, although the experimental elucidation of the problem is beset with many difficulties on account of the capacity of the intestinal wall to resorb as well as to secrete fluid. Frouin finds that the upper part of the duodenum secretes three times as much juice per unit of length to a given dose of exciting agent as the lower part and the power of secretion diminishes still further in the jejunum. When the secretion is permitted to discharge to the exterior the secretory activity rapidly diminishes but when it is reinjected into the animal activity is revived. These facts speak strongly for a secretin which is continuously "circulated" after the manner of bile salts.

Enzymes of the Intestinal Juice. *Enterokinase.*—This is, so far as we know, the only instance of an enzyme which acts upon another enzyme to render the second active. It has already been discussed in relation to its action on trypsinogen (p. 728).

Erepsin.—The disappearance of peptone when it comes in contact with the intestinal wall was for a long time thought to be due to synthesis back to albumin. In 1899, however, Caparelli[66] attributed this disappearance to an enzyme, and in 1901 Cohnheim[75] proved it, naming the enzyme *erepsin*. We now know that erepsins occur in practically all organs of the body as well as in plants.

The peculiarity of erepsin is that with a single exception (casein) it cannot, like pepsin and trypsin, act upon albumin or albumoses. It may be distinguished from trypsin by adding blood serum to a mixture of the two. Serum contains an anti-trypsin which will effectually stop the action of trypsin but will not interfere with erepsin. If pepsin and trypsin are allowed to act simultaneously on two different samples of the same protein it will be found at any given stage (after a few hours) that the average molecular weight in the tryptic digest is considerably lower than with pepsin. If phosphotungstic acid is used it will be found that a considerably larger fraction of the total nitrogen occurs in the filtrate after trypsin than after pepsin. Most of the bodies non-precipitable by phosphotungstic are amino-acids, but a portion of them are compounds which cannot be further broken down by trypsin much less by pepsin. Erepsin, however, can attack these compounds and reduce them all ultimately to amino-acids.*

It is interesting to know that each succeeding enzyme of the proteolytic series can destroy the one before it, but cannot be destroyed by its predecessor. Thus Harley[172] has shown that trypsin even in a slightly acid medium can very materially weaken or indeed entirely arrest the action of pepsin upon fibrin, while pepsin exerts no action whatsoever upon trypsin. Likewise Effront[109] has shown that erepsin in the same digest with trypsin very markedly weakens its action. It is in each case the more active enzyme which destroys the less active. Pepsin is digested by trypsin and thereby destroyed and trypsin in its turn yields to erepsin.†

Amylase and Maltase.—The action of these enzymes of the intestinal juice cannot be distinguished from that of the corresponding enzymes furnished by the pancreas. The only reason for making separate mention of them here is to indicate the rational feeding which might be resorted to in the very rare cases of obliteration or stenosis of the pancreatic duct. In the infant all of the food stuffs could be acted upon to an appreciable extent without the aid of the pancreas. It is even claimed by some[49] that digestion of fat in the intestine is possible without either pancreatic juice or bile. Certainly there would be no reason for withholding either carbohydrates or proteins and a fairly good utilization might be established if care were taken to replace the alkali missing for want of pancreatic juice.

Invertase and Lactase.—These two inverting enzymes of exactly similar nature may be discussed together. Both are found in the intestinal wall itself, and both from birth[307] act upon disaccharides each of which yields one molecule of glucose and one of a different monosaccharide. Cane sugar is rarely if ever absorbed unchanged. Invertase which splits it into glucose and fructose is found more abundantly in the extract of intestinal mucosa than in the secretion and more abundantly in the upper part of the intestine (duodenum, jejunum) than in the ileum.[370] It follows that cane sugar is broken up in the very act of its absorption and is absorbed very soon after leaving the stomach. Invertase is certainly one of the most invariable enzymes of the intestinal tract, being always present in the intestinal lining of mammal at births, and can often be found in the fetus when all other enzymes are lacking.[77] Lactose is never found outside of the class of mammals, and in these only so long as they are fed on milk. After the disappearance of the enzyme it may be brought back by renewal of a milk diet, or any other containing milk sugar. Pautz and Vogel[345] state that lactase occurs in abundance only in the jejunum.

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* Cohnheim has shown that of the total N in syntonin, 29.9 per cent. is precipitable by phosphotungstic acid after digestion with pepsin and erepsin, while 27.14 per cent., after acid hydrolysis, consists of arginin, lysin, histidin, etc., likewise precipitable by phosphotungstic.

† It is for reasons which will appear obvious from this discussion that the quantitative examination of infants' stools for enzymes is fraught with so much uncertainty.

Bile.—The third fluid of the intestine represents in part a secretion and in part an excretion. Judging by the relative size of the liver in the infant as compared with the adult this organ is one of special importance in early life. It is probable, however, that this concerns the metabolism of food beyond the alimentary wall rather than its digestion. In the latter function the bile plays the same part as in the adult; namely, (1) it aids enzyme action in the case of lipase (p. 731); (2) it aids the formation of an emulsion by diminishing the surface tension between fat and water; (3) it furnishes alkali (Na) for the formation of soaps; (4) it dissolves the higher fatty acids which are insoluble in the other juices of the intestine, as they are set free, and does the same to some extent for otherwise insoluble soaps.

In the opinion of Pavloff[346] there are only two substances which stimulate the secretion of bile upon contact with the intestinal lining; namely, fat and albumose. The effectiveness of fat as a stimulant to biliary secretion is readily understood since the discovery by Moore and Rockwood[309] that in the presence of sodium soap bile can dissolve free fatty acids very readily. The significance of bile for protein digestion has been variously interpreted. One view is based upon the observation, which is readily made in dogs with duodenal fistulæ, that bile salts in the presence of hydrochloric acid form an insoluble precipitate with the albumins or albumoses of the chyme. This precipitate or curd is redissolved as soon as the reaction becomes neutral or alkaline. Since precipitation splits off any pepsin which may be linked to the protein it has been argued that bile seems to carry the protein over from the peptic sphere of influence and to deliver it to the tryptic mandate. Another view has been that by means of this precipitation proteins not yet sufficiently reduced by digestion are prevented from being absorbed. Possibly phenomena of food allergy in children are associated with a deficiency of bile.

Physico-chemical Factors.—The absorption of food is one of the functions which can be explained in part by the laws of physical chemistry. Water, for example, will pass from the intestinal tract into the blood stream in obedience to the osmotic pressure of the electrolytes and non-electrolytes of the blood plasma, just as water will pass in the reverse direction when the intestine contains a hypertonic solution of magnesium sulphate. According to the latest ideas regarding osmosis[286] there seem to be at least three factors involved whatever the nature of the membrane across which the molecular forces operate: (1) the attraction of the membrane for the solvent, determining its imbibition; (2) the presence of solutes affecting this imbibition; and (3) the mutual attraction between solute and solvent. Assuming for any given system that (2) and (3) are constant, osmosis would then depend upon the imbibition of the membrane, and if this is different on the two sides of the membrane, the movement of liquid would be forced in one direction. Now one effect of imbibition is to alter the size of the pores and it has been shown that enlargement of the pores can change positive into negative osmose, *i.e.*, toward the acid side. If a membrane separate two fluids one of which is more acid than the other, this one will be electronegative and the osmosis should be in that direction, since electro-endosmosis is usually toward the negative pole. This view harmonizes with the fact that osmosis in the stomach is from the blood which is alkaline; while in the intestine it is toward the blood which is more acid than the intestinal contents. The acidity of the stomach then explains the fact that very little if any absorption of food takes place from that organ, while the change to alkali in the intestine accounts for absorption there. The writer[320] has shown in a series of experiments published as yet only in preliminary form that when two loops of the intestine of equal length are filled with a solution (about 2 per cent.) of glucose, one of the loops containing 0.3 per cent. Na_2CO_3 and the other an equivalent amount of HCl, the greater absorption always occurs from the alkaline loop, no difference where it is located. Hamburger, Girard, Flusin and several other students of bioelectric phenomena believe that all such absorption activities, even those of hypertonic solution, can be explained by physico-chemical laws. Others, like Cohnheim, are equally positive in their belief that a selective or "vital" activity is necessary to supplement the explanation. Cohnheim[77] studied comparatively the absorption of grape sugar from serous cavities and from the intestine. In the former not especially constructed for absorption there was an interchange by diffusion between the sugar solution and the blood. Sugar passed from the serous cavity into the blood stream, while sodium chloride and carbonate with some protein as well passed thence into the serous cavity. Besides this there was a diminution of the fluid by a process which could not be called diffusion because it was stopped by the action of poisons like sodium fluoride as soon as the membrane was dead. In the mammalian intestine what happened was quite different: (1) absorption was much more rapid; (2) diffusion of sugar was not independent of the movement of fluid, but solvent and solute moved as if chained together; (3) constituents of the blood passed over into the intestinal cavity only to a very slight extent. In other words, the movement was wholly unidirectional. Salt and other readily absorbed material can pass readily from lumenal to serous side but not from serous to lumenal side. These phenomena depend upon two distinct properties of the intestinal wall: (1) unilateral impermeability and (2) the capacity to transport water with its solutes from intestine to blood independently of osmotic pressure. Weak fluoride solution abolishes the latter property without injury to the other while weak arsenic solution does just the reverse. Cohnheim expressed the opinion that the resistance to outward diffusion is a property of the capillary endothelium and the absorption proper one which belongs to the intestinal epithelium.

It may be admitted frankly that there is much about absorption and secretion and other kindred phenomena concerned in the metabolism of food that cannot yet be reduced to physico-chemical laws; but this is no ground for discouragement of the belief that they will be so explained in time. It is less than a century since the digestion of food was a complete mystery. Digestion and absorption go on simultaneously throughout the alimentary tract; for even in the stomach, where but little absorption of food occurs, absorption of the gastrin is necessary to insure the continuous progress of digestion. The last stages of digestion of both proteins and carbohydrates are inseparable from absorption. Erepsin and lactase act upon already diffusible products in the very act of being absorbed.

Absorption of Carbohydrates.—Proof that carbohydrates are absorbed only as monosaccharides can be established by several different experiments. Ferments capable of splitting the starches and disaccharides are known to exist in the intestine and indeed the monosaccharides are easily demonstrable in its contents. The only question remaining is, how do we know that only simple sugars like glucose and galactose are permitted to pass and not the double sugars like sucrose and lactose? Weinland[461] answered the question as regards milk sugar very conclusively. In animals which had no lactase in the intestine milk sugar was not absorbed no matter how long it remained in the cavity. On the other hand, animals in which lactase could be demonstrated absorbed milk sugar as readily as grape sugar and formed glycogen from it just as well. If a series of single sugars and double sugars be injected subcutaneously it is found that the single sugars all disappear and are utilized while the double sugars are excreted quantitatively in the urine.[453] Since carbohydrate is absorbed almost exclusively through the blood stream and not through the lymph it must pass directly to the liver. Here the glycogenic function comes into play in proportion to the concentration of the sugar in the portal vein and in conformity with the needs of the tissues for energy. On account of the imperative needs of the infant for fuel, the regulation of this easily mobile material is of great importance. Hence the size of the liver* in the newborn. No satisfactory deter-

* The fetal liver begins to assume its carbohydrate function in the rabbit[271] at about the last quarter of the gestation period. Up to this time glycogen was stored exclusively in the maternal placenta. Goldman[156] found the same storage of glycogen in the maternal side of the placenta in the mouse; but Driessen[103] claims this is not true of the human placenta, from which we may perhaps infer that its retention in the liver of the human fetus begins at an earlier date. However, the older idea of Pflüger that embryonic tissues are particularly rich in glycogen and that the newborn is exceptionally well provided with this nutrient

minations of the glycogen in the liver of the newborn infant are at hand, doubtless for the reason that the liver cannot be secured sufficiently early after death; for glycogenolysis sets in the moment the supply of oxygen by the circulation ceases. In the liver of the mature fetus of the dog Butte[60] found 8.7 per cent. glycogen as against 0.4 per cent. in the liver of the mother 15 minutes after death. It should be borne in mind that there is a definite limit to the power of the alimentary tract in the infant no less than in the adult to absorb sugars. An excessive amount produces serious disturbances, in which the influence of bacteria plays an important part.

Absorption of Fat.—Fat absorbed as fatty acids and glycerin is immediately resynthesized into neutral fat and reaches the blood stream, by way of the thoracic duct, as such. Proofs of this proceed upon the following lines. In the lower part of the small intestine scarcely any neutral fat is encountered, but abundance of soap and still more free fatty acids. Soaps are not found in the epithelium, and neither soaps nor (more than a small percentage) fatty acids are found in the lymph channels. That which intervenes in the epithelium may be, so far as the staining reactions are concerned, either fatty acids or neutral fat. The incontrovertible fact is, that whereas one finds on the intestinal side mainly fatty acid, when the lymph stream is gained it has (practically all) become neutral fat. Soaps indeed are toxic. That none of the fat can escape cleavage before being absorbed is proved by the fact that attempts to bring about absorption of fats like lanolin,[78] vaselin,[46] and paraffin,[181] which can be finely emulsified but not saponified by the pancreatic lipase, have always proved futile. Fats must first be made soluble in water before they can pass the epithelium. With the aid of bile salts this can be accomplished for fatty acids but not for neutral fats. Hence the necessity for cleavage. Having reached the circulating fluid there is no further necessity of a water solution. The requirements for circulation can be served by a suspension or emulsion fine enough to pass the capillaries. Synthesis therefore occurs probably while the bile salts are still present to aid emulsification, after which they are recovered by the liver and concentrated once more in the bile.

The significance of bile for the utilization of fat in infancy is well illustrated by the observations of Koplik and Crohn[239] upon a child 10 weeks of age with complete absence of bile from the intestines through congenital obliteration of the bile duct. Examination of the stools showed an absorption of only 48 per cent. compared with a normal utilization of 88 to 96 per cent. The authors compare their results with those of Niemann[325] on a child nine months of age in which the biliary function had been destroyed by cirrhosis of the liver and whose

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material (p. 579) has not been confirmed by the most recent observations.[297] The presence of glycogen in the fetus (and therefore the newborn) has the same significance as in the mature liver. It cannot be expected in the absence of an adequate supply of carbohydrate or an excess of protein in the food.

absorption on a buttermilk diet was only 28 to 38 per cent. of the fat ingested.

Digestion and absorption of fat proceeds very slowly compared with the other food stuffs. Aside from the slow discharge of fats from the stomach (p. 699) is the observation of Pavloff that fats retard the movements of the intestine. After a very heavy meal of fat the stomach of a dog may discharge only 4.3 per cent. of the total fat per hour and the intestine may contain at one time not more than 5.5 per cent.[134] At this rate it would require 24 hours to evacuate the stomach. In the infant normally fed events obviously must proceed much more rapidly even with the highest fat formulas (p. 699). Fat is absorbed chiefly in the lower part of the small intestine (ileum). In experiments with poly-fistulous dogs Levites[266] observed that in the neighborhood of 10 per cent. of fat may be absorbed in the duodenum and that practically all is removed before the ileocecal valve is reached. This is in agreement with older observations which show that while the large intestine has the power to absorb fat and soaps, to produce a physiologically significant effect it would be necessary to retain an emulsion of fats therein for many hours. Sufficient lipase is carried in the fecal mass to accomplish this cleavage in the course of time.

Absorption of Protein.—It is impossible as yet to prove whether or not all the protein of a meal is absorbed in the form of amino-acids. Many statements that they are so absorbed exclusively are encountered in recent literature based upon the observations of Folin and Denis,[129] Van Slyke[445] and others, showing that the individual amino-acids are quickly absorbed. That a considerable part of the protein reaches this stage under the influence of trypsin alone, leaving erepsin out of account, is demonstrable[249] and the discovery of the latter ferment and its peculiar relations to the intestinal mucosa together with the facts regarding its action *in vitro* which have been discussed on page 732 make it very probable that under ordinary circumstances this is the fate of all food proteins just as truly as that carbohydrate and fat are reduced to their corresponding prototypes. But it is equally undeniable that peptones, albumoses and even syntonin are soluble in water or that they may be absorbed as such under unusual circumstances. The difficulties attending conclusive proof may be illustrated by the following example. Suppose a dog has had a meal consisting of 200 gm. of meat containing 6 gm. of nitrogen and that the whole of it is absorbed in six hours. During this time the entire volume of the blood has circulated through the heart perhaps 1000 times. For each complete circulation then something like 6 mgm. of nitrogen has been added to the whole of the blood. Thus far no technique has been devised which is capable of demonstrating an increase with such a rate of absorption in a moderate amount of blood. With larger quantities of food, however (up to 1000 gm. meat at a single meal), a significant rise of amino-acid nitrogen in the dog's blood can be seen.[466] Amino-acids injected directly into the blood or fed in pure solution in large amounts can not only be found in the blood but can be followed to the tissues,[129, 447] which lay hold of them with great avidity. From these facts it is inferred that the tissues synthesize their own proteins from the ultimate cleavage products, disposing of the excess above their needs by deamination and conversion to urea. In the infant no increase in the amino-acid or even of the total non-protein nitrogen of the blood has been demonstrated following food. Schultz and Pettibone found the normal content of the non-protein nitrogen about the same as in the adult, but there was no visible variation in relation to the period of feeding. It should be emphasized that the evidence above mentioned by no means excludes the possiblity of absorption of protein by the infant in other form than amino-acids. But it makes the old theory of synthesis at the intestinal wall unnecessary to account for the disappearance of the cleavage products. The rapidity of the circulation together with the very prompt absorption of the crystallizable products into the tissues from the blood are held to favor the theory of local synthesis at the place where new tissues are being formed. Details of such a process, however, are wholly lacking. Whether muscle cells, gland cells, etc., must wait until the appropriate building stones for their particular types of architecture are at hand, or whether each cell has the power of molding these elemental structures to its needs, we do not know.

It seems to be established that under certain circumstances proteins can be absorbed in undigested or at least partially digested form. A small loop of the dog's intestine has been known to take up 6 gm. of serum protein in 50 minutes. It is scarcely possible that it could be completely hydrolyzed in so short a time. Hamburger and Sperck[169] failed, however, to obtain any evidence of absorption of unchanged protein by infants in sufficient amount to give a precipitin reaction although such a reaction could be readily shown after parenteral injection of minimal quantities. If foreign protein even in small quantity were absorbed from the alimentary tract it should appear in the urine. Normal infants have been tested by the precipitin reaction for proteins of egg and meat by Lust[277] and by Hayashi,[175] and for egg and milk both by the precipitin and anaphylactic reactions by Schloss and Worthen,[387] but with only negative results. In nutritional disorders, especially those of the severer types, all observers agree that these proteins may appear in the urine as well as in the blood. Formerly it was supposed that milk albumin was absorbed unaltered and great emphasis[388] was placed upon the advantages of native ("arteigenes") albumin in the nourishment of the infant, for the reason that such protein could contribute directly to its nourishment without denaturalization, whereas foreign ("artfremdes") albumin must first undergo digestion and complete tran formation. Proof is lacking however that lactalbumin is not digested as is the casein; there is no evidence that such albumin is identical with serum albumin; and finally foreign blood proteins can be absorbed unchanged from the alimentary tract only in the first few days of life[146] and then only in very small amounts.

It is well known that albumoses and peptones[437] injected into the blood stream behave as foreign bodies and are eliminated in the urine. Polypeptids[5] formed synthetically are not eliminated and it may be presumed are utilized or disposed of as amino-acids. The weight of evidence plainly is that the absorption of protein before it has been profoundly disintegrated is quite exceptional if not entirely abnormal.

At what stage of digestion does the protein of cow's milk cease to be cow's protein and become mere building material? The occurrence of plasteïns as synthetic products in digestion by pepsin as well as by trypsin, it has been surmised, should afford a solution of the question. For the reason that peptic-digested protein no longer has antigenic properties, it is not possible to use the cleavage products directly. A synthetic product however might serve the purpose. Kaffl-Lenz and Pick[219] acting upon this conjecture found that plasteïns from artificial peptic digestion have antigenic properties but are not specific, since the immune bodies react as well with plasteïns from heterologous proteins as with those from the protein used as antigen. Plasteïn being of the order of complexity of proteoses (heteroalbumoses),[264] and proteoses being formed in peptic digestion, these authors draw the conclusion that the stomach puts an end to the specific nature of the food protein.

Composition of the Feces of Infants.—This section will be devoted to a brief discussion of the components of the feces of the infant with special reference to their sources. It makes no pretense to interpret the stools clinically except as such interpretation may be aided by purely physiological considerations. It is the principles of metabolism with which we are here chiefly concerned. For the assistance which it may render to future discussion of the substance metabolism and, for that matter, the energy metabolism, as well, the aim will be to account for the main constituents of the feces and see how they may differ from the feces of the adult.

Nature of the Feces.—Students of metabolism in adults are familiar with the view which regards all indigestible substances in the feces as distinctly extraneous or "abnormal." The writings of Prausnitz[357] and others of the Munich school of metabolism are responsible for this view. Prausnitz fed six different persons alternately on meat and rice which was well cooked and found that the feces from the two kinds of diets in all the subjects contained the same amount of nitrogen, ether extract and total ash. In other words, the protein—or extractive constituents, the fatty substances and the mineral matter were the same in amount whether the person ate food containing on the one hand a mere trace of protein, a large amount of carbohydrate and no fat, or on the other one containing 20 per cent. protein, 5 to 15 per cent. fat and no carbohydrate. Bischoff and Voit[42] many years earlier had shown that a dog produces during starvation the same kind of feces as when he is fed on meat; also that while the amounts increased with larger feedings of meat they were by no means proportional thereto.

It is shown from these experiments that neither the character nor the amount of the feces is determined solely by the food. Prausnitz applied the term "normal" to feces which result from the digestion and absorption of well-cooked and perfectly digestible food. The main source of such feces was demonstrated by Fritz Voit[454] who isolated a loop of the intestine (Thiry-Vella fistula) in the dog and found after three weeks that the cavity of this loop, entirely untouched by the food which the dog had received, contained a mass of material which had essentially the same composition as the feces from the restored canal. The intestinal wall produced feces without having been touched by food. The characteristic color of the feces was lacking because bile was excluded but the odor was present because putrefaction had taken place. While some objection has been raised to this experiment[231] which was originated by Hermann, it has served more than any other line of observation to impress the fact that feces are to a large extent produced by the alimentary wall and its accessory structures. Naturally they are not produced in the form and consistency found in the evacuations, for water has been absorbed in the large intestine, some digestion has occurred, bacteria have used up for growth of their own bodies a considerable part, and so on. The original form was that of the alimentary secretions. It is conceivable indeed that feces might consist of nothing else than residues of the alimentary secretions. Such a state of affairs would presuppose that all of the food which had called out the secretions had been digested and absorbed. Since this state of perfection is never attained, however, there is little to be gained by basing thereon any definition or standard. That a considerable portion of the infant's feces is derived from the same source is nicely proved by the following observation by Keller.[227] For therapeutic purposes an 11-months baby was fasted for two days during which the urine and feces were collected separately for analysis. The feces for one day contained 0.072 gm. N and 0.0292 gm. P_2O_5. The next day the child received in watery solution a small amount (5.5 gm.) of "Protogen," a protein containing no phosphorus, and the day following double the amount. The feces for these two days were separated and found to contain daily 0.041 gm. P_2O_5. The increased activity of the alimentary tract occasioned by the ingestion of this small amount of food *containing no phosphorus* had raised the output of phosphoeus through the alimentary wall 40 per cent. The amount of fat in the feces of the protogen period was 0.82 per cent. or a daily elimination of 0.0276 gm. fat and fatty acids.

When we remember that the alimentary secretions reduced to a dry basis are rather rich in protein and inorganic salts we have, in the light of what has gone before, the clue to the fundamental composition of the feces. Observations on children very similar to the old experiment of Bischoff and Voit mentioned above are now rather plentiful. L. F. Meyer[301] gives the following results of adding a large amount of casein to the food of two healthy infants upon which they had been brought into N equilibrium.

TABLE 50.—INFLUENCE OF EXCESS PROTEIN ON FECAL N (L. F. MEYER)

Child	Period	N in food	N in feces
A	Preliminary	1.027	0.178
	Same food + 16.5 gm. casein	3.552	0.256
B	Preliminary	1.922	0.183
	Same food + 21 gm. casein	4.773	0.177

Trebling the intake of nitrogen in the first case increased the output of nitrogen in the feces about 50 per cent. Multiplying the intake by two and a half in the second case did not increase the fecal nitrogen at all. If such observations were not amply supported by numerous others of a similar nature one would be inclined to question the separation of the feces. But when one remembers that digestion is accomplished by enzymes which act by catalysis and not by mass action, it is clear that in a fluid medium like milk there is no reason for increasing the secretions in proportion to the weight of nutrients ingested. Given thorough mixture in the intestine the same output of gastric, pancreatic, and intestinal juices might very well accomplish three times the digestion of protein and be followed by 100 per cent. absorption of the increase. Neither the dry mass of the feces then nor the weights of their constituents would necessarily be augmented.

The exact character of the feces of the normal infant will depend upon the number of extraneous substances superimposed upon the fundamental components by: (1) the completeness of digestion and absorption, secondary to which is the vigor of peristalsis; and (2) the character of the intestinal flora. Such adventitious substances are of great importance in diagnosis. For example, the color and odor of the stools depend (1) upon the kind of food and how much of it is passed undigested whether because of increased peristalsis or poor adaptability; (2) upon the amount of putrefaction or fermentation; and (3) upon the amount of bile secreted and reaching the digestive arena. The consistency depends primarily (1) upon the amount of water remaining unabsorbed, and (2) upon the amount of fat.

Characteristic Ingredients.—Pursuing the subject from the vantage point already taken regarding the nature of the feces in the infant, we shall find ourselves in better position to appreciate the significance of certain constituents which are so constant as to be regarded as peculiar to the feces. Among these, though by no means most prominent, are the digestive enzymes. Why are they present in the feces? There is only one answer: Because they belong there. If the feces were primarily or mainly undigested food, they would not be present except by accident, while as a matter of fact they are never absent except by accident. V. Jaksch[442] found invertase as a regular constituent of infant feces, Pautz and Vogel[345] vouch for the presence of lactase, and Moro[310] may be quoted among many others who have had no difficulty in finding a diastatic enzyme. The proteolytic and lipolytic enzymes are less constant because, as already noted (p. 733), they are much more readily destroyed. Nevertheless Hahn and Lust[168] were able to find them in all kinds of stools both normal and pathological with the exception already given (p. 728).

The odor of feces is so characteristic and so familiar that its identification would be accepted in any court of law upon the word of any reliable witness. The odor of infant stools is not so familiar because they represent a rather unusual state of affairs. What everybody recognizes as the odor of feces is the odor of certain definite putrefactive products: Indol, skatol, phenol, and the gases H_2S, CH_4, NH_3, etc. In the newborn the intestinal tract is sterile and it is only after putrefactive organisms have been introduced in the food or have gradually established themselves by direct invasion of the rectum and colon that the characteristic odor appears. There are many testimonials to the fact that the specific putrefactive products[42] indol, skatol and phenol are not found in the fresh feces of breast-fed infants or even of infants fed with care from the bottle. They begin to appear in demonstrable quantity when other foods than milk are taken. Oxyacids, however, particularly lactic acid and fatty acids like butyric acid, are present but they are accounted for by the same processes of spoilage which occur in milk outside the body. The bacteriology of the infant's alimentary tract should be considered very briefly in this connection. For more extended discussion see Chapter XXVI. Kendall[228] notes that the earliest organisms gaining entrance to the alimentary tracts are spore-forming, but they find only the detritus of the fetal alimentary wall to feed upon. "When breast milk has had a chance to thoroughly permeate the intestinal tract, new organisms appear, organisms which have a definite relation to the type of food which is presented to them. It will be remembered that breast milk contains essentially 7 per cent. of lactose, about 3 per cent. of fat and but 1½ per cent. of protein. Carbohydrate is, therefore, the dominant food. It is noteworthy that the organisms which appear in response to this diet are those whose metabolism is intimately associated with the utilization of sugar. These organisms thrive but poorly in a medium from which milk is excluded. When other foods begin to replace the breast milk there is a definite change in the types of bacteria represented in the intestinal contents. The obligate fermentative bacteria such as the B. bifidus are replaced by more plastic forms and by the B. coli which can accommodate their metabolism rapidly to dietary alterations. The B. coli, for example, can thrive equally well on a medium in which carbohydrate is absent. It might appear from this rather definite alteration of types of bacteria in the intestinal tract following changes in the character of the food that the food alone determined the intestinal flora. This may be somewhat influenced by the intestinal secretions." A change in the character *and amount* of the intestinal secretions doubtless takes place during the transition from fluid to solid foods, and these changes as well may influence the flora. Further it is known to be exceedingly difficult to change permanently the intestinal flora of an adult. Perhaps the uniform character and composition of the secretions is the principal element of the inertia.

Intimately associated with this question of putrefaction is the color of the feces and this in turn depends upon the transformation of bile pigments. Without putrefaction in the intestine the bilirubin of the bile would not be changed to hydrobilirubin which imparts the brownish-yellow color to the feces of the adult; for the last-named substance was shown by Maly[281] to be derived by a process of reduction. In the intestine this is accomplished under the agency of free hydrogen produced by putrefaction. Schorlemmer[394] reported the first appearance of hydrobilirubin in the feces of breast-fed infants very definitely on the fourteenth and fiftteenth day of their lives. With infants fed in part or exclusively on cow's milk the first traces appeared as early as the seventh day. These traces however are not sufficient to alter the predominating color of the feces. According to Schikora[383] the deep change in color comes with the transition to solid food, and Glarre[155] finds that this is coincident with the appearance of urobilin in the urine.

The reduction of cholesterin to coprosterin which takes place in the adult under the influence of putrefactive organisms does not occur in the meconium. Müller[314] found unchanged cholesterin in the feces of the infant on milk diet, but when mixed diet was introduced coprosterin only could be located.

One other constituent may be named because of origin, namely, the nuclein from which, according to Weintraud,[462] purin bases may be produced by prolonged hydrolysis with sulphuric acid. This nuclein occurs also in the meconium and in later stools of infancy; but before putrefaction sets in it will yield by hydrolysis uric acid instead of purin bases, showing, as Weintraud believed, that it has undergone a process of partial oxidation in the canal. Since it occurs in the meconium this phosphorated body must have its origin in the intestinal tract itself.

Every laboratory worker who has had experience with powdered feces, particularly the feces of starvation, has been struck by the almost mineral character of the dust. The same basic and acid radicles are found in the ash as are found in the urine, though by no means in the same proportion. Martin Thiemich in Feer's Lehrbuch has stressed the origin of many of the mineral ingredients from the alimentary secretions. It is unfortunate that little is yet known of their quantitative relations in the starvation feces.

Utilization of the Food Stuffs in Normal Infants and Older Children.—The term utilization as applied to the food in the alimentary tract has been employed by some writers as entirely synonymous with absorption, but by others as denoting the difference between intake and output through the intestine. It is in the latter sense that the term will be used in this chapter. If the feces were composed of unabsorbed residues of the food and nothing else, estimation of the absorption of each food stuff would be a relatively simple matter. Precisely because this is not the case the percentage of certain food stuffs which escape digestion or absorption or both can never be stated with exactness. Only in one instance, namely carbohydrates, can we say that the quantity found in the feces represents unabsorbed foods; for they are not found in the alimentary secretions themselves nor in the feces of starvation. Fats, it is true, occur in only very small quantity (p. 741) and for all practical purposes the food fat minus the fecal fat gives the absorption figure. With proteins and mineral salts a considerable portion always belongs to the secretions. Still worse the exact quantity can never be known; for even if a starvation period could always be used to introduce an absorption experiment the amounts found in the stool would not be equal to the strictly endogenous production of a feeding period; for the moment food is given the volume of secretions and the mass of contained solids increase. The difference between utilization and absorption should be borne clearly in mind.

Utilization of Proteins.—Because of the facts just given it has become customary to think of the fecal protein (or total nitrogen) in absolute rather than in relative terms. The factors which influence the amount of nitrogen lost by the alimentary tract can be discussed just as well in these terms, and it is quite justifiable in balance experiments to regard the total nitrogen as "loss" whatever its source. The only embarrassment is that "percentage absorption" cannot be expressed with the same accuracy as it can, for example, for fats. Neither can the total nitrogen of the feces be regarded as "metabolized" or "katabolized protein" in the sense in which the nitrogen of the urine can be so described; for (with the exception of the small amount of fecal urea, see below) it has not been through the deaminizing process.

Factors Influencing the Fecal Nitrogen.—Only two observations on the loss of nitrogen by the feces during starvation in infancy have been recorded and they are not at all concordant. Keller[227] in the case of an 11-months bottle-fed child weighing 4300 gm. in two fasting periods which began 18 and 30 hours respectively after the last feeding found 0.072 gm. and 0.097 gm. nitrogen in the stool for a 24-hour period. Amberg and Morril[16] in the case of a five-months breast-fed infant weighing 4800 gm. collected the stools throughout a fasting period of 48 hours, beginning 18 hours after the last feeding, and found 0.069 gm. nitrogen in the entire feces or 0.035 gm. for one day. The larger loss from the alimentary tract of the bottle-fed child is in agreement with the observation of Schlossmann and Murschauser[389] that more nitrogen was found in the urines of fasting infants previously bottle-fed than from those which had been previously breast-fed, but the two phenomena are not necessarily associated. The difficulty of accurately separating the feces of a fasting period precludes any further deductions from the data at hand. Possibly the two values given represent something near the minimal and maximal values.

Numerous experiments,[86] on the other hand, can be cited showing the influence of different quantities of protein in the food upon the output of nitrogen by the intestinal tract. A few instances must suffice. Thus a healthy eight-months-old infant,[468] fed in one period a meager diet of whole milk which did not quite cover his requirement and later a larger quantity of the same food upon which he gained weight, gave the following results in daily quantities.

	Food nitrogen, grams	Fecal nitrogen, grams
¾ liter whole milk	3.528	0.296
1¼ liters whole milk	5.88	0.415

During the first period the child was approximately in N equilibrium but lost calcium and phosphate from its body. In the second period it was retaining both minerals as well as nitrogen.

The idea which formerly prevailed among pediatrists that the failure of artificial feeding could be traced to the relative indigestibility of cow's milk casein has been many times disproved by accurate experiments. In fact it is found not infrequently that there is even smaller loss of nitrogen by the feces on modified cow's milk than on breast feeding. The following table from Orgler[334] is highly instructive.

Table 51.—Breast-fed Compared with Artificially Fed Infants (Czerney and Keller, after Orgler)

Kind of food	Keller		Keller		Orgler		Orgler	
	Nitrogen intake	Fecal nitrogen	Nitrogen intake	Fecal nitrogen	Nitrogen intake	Fecal nitrogen	Nitrogen intake	Fecal nitrogen
Breast milk	1.51	0.29	1.87	0.24	0.69	0.17	0.97	0.21
Cow's milk	2.05	0.27	2.23	0.14	0.92	0.14	1.10	0.20

In every instance the intake of nitrogen in the form of cow's milk is greater, and yet the fecal nitrogen is less than on breast milk. The addition of cow's milk in the form of supplementary feeding need not be feared therefore from the standpoint of utilization of proteins. Even changing from breast milk to protein milk with a very much higher content of nitrogen does not always influence the fecal nitrogen materially as the following instance from Peiser[347] will show.

	Food Nitrogen	Fecal Nitrogen
Wet nurse milk	1.144	0.190
"Eiweissmilch"	4.01	0.296

Continued use of protein milk for some time, however, may result in a gradual increase of the fecal nitrogen to much higher values. Hoobler[208] kept a healthy robust child of two months under observation for 16 days. The first four days he was fed one-third whole milk with 5 per cent. dextrimaltose. He was then placed on a slightly increased protein diet and the following day was put back again on low protein. This continued each alternate day gradually increasing the protein intake until the last five days when the child was placed on maximum quantities of protein in the form of albumin milk, containing 56 per cent. of the total calories in the form of protein. The fecal nitrogen increased as shown below.

	Distribution of calories, per cent.			Food N	Fecal N
6th day.....	15.3 prot.	24.7 fat	60 CH	1.92	0.187
10th day.....	43.7 prot.	29.3 fat	27 CH	5.30	0.518
13th day.....	56.2 prot.	0.0 fat	43.8 CH	6.61	0.646

Adding sugar to whole milk has the effect ordinarily of increasing the fecal nitrogen through increased peristalsis. The following illustration, again from Czerny and Keller, may be given:

TABLE 52

Experiment number	Food	Food N	Fecal N
I	½ cow's milk	1.853	0.125
	½ cow's milk + 75 gm. maltose	2.04	0.239
II	Whole milk	3.832	0.185
	Whole milk + 75 gm. maltose	3.830	0.347

Adding fat usually has no effect on the nitrogen as the following experiment from Freund[136] illustrates:

TABLE 53

Experiment number	Food	Food N	Fecal N
I	Buttermilk	3.389	0.278
	Buttermilk + butter	3.047	0.311
II	Buttermilk	3.405	0.379
	Buttermilk + butter	3.114	0.338

Takeno[417] reports, however, that cod liver oil may cause a reduction in the fecal nitrogen, and Aschenheim[23] claims the utilization of N is better after a fat-rich than after a fat-poor milk.

In all of the experiments thus far cited the fecal nitrogen makes up about one-tenth the quantity of the food nitrogen. The utilization is in the neighborhood of 90 per cent.—absorption of course considerably better than this.

Contrasted with these figures for milk diet are the much higher values for fecal nitrogen after a cereal diet. Rubner and Heubner found an apparent absorption after an all-cereal diet of only 56 per cent., and Niemann,[324] who fed the same child at different times upon different kinds of food, obtained the following comparison when nothing but cereal was given:

Age, weeks	Food	Food N	Fecal N
16	Buttermilk and sugar	3.77	0.283
22	Skim-milk and sugar	4.57	0.40
40	Cereal	1.57	0.395

In absolute figures, which are the important ones, the output of nitrogen was not unfavorable, but in proportion to the nitrogen of the food or as percentage utilization the contrast is very poor. A better illustration of the fallacy of calculating absorption of nitrogen to the neglect of the actual source of the nitrogen could not be devised. The actual reasons for the relatively high nitrogen are: (1) the low nitrogen content of the food; and (2) the increased peristalsis. Probably there is not an actual increase in the volume of secretions.

Different Forms of Nitrogen in the Feces of Normal Infants.—Degradation products of proteins, as we have seen (p. 743), make up an important part of the feces. Some of these doubtless are left-over products of protease action in the small intestine. Others are characteristic of the action of putrefying bacteria. Of the first group are to be mentioned especially proteoses and amino-acids; and of the second ammonia, indol, skatol and phenol. To the latter group, since its occurrence in culture media of proteolytic bacteria has been rendered highly probable by Kendall[229] and in infant's stools still more probable by Gamble[144] and Van Slyke,[448] must now be added urea. The word probable must be used in both instances because Kendall did not employ urease but a purely chemical method, and while both Gamble and Van Slyke and his collaborators used urease Van Slyke at least was not quite certain that the urea found was not due to slight contamination of the stools with urine.

It is only recently that attempts have been made to fractionate the nitrogen of infant's stools so that their significance in metabolism might be learned. This field seems to offer such promise that it may be considered useful to give in this place the methods employed. To the reader who is familiar with the methods of separating protein fractions introduced by Van Slyke and the methods devised by Folin and others for separation of the nitrogenous bodies in the urine these methods will be old friends.

Methods for the Determination of Different Forms of Nitrogen in Stools. (1) *Total Nitrogen.*—Modification[144] of the micro-method of Folin. The 24-hour specimen of stool is placed in a weighed dish and thoroughly mixed by stirring and rubbing with a spatula, water being added if necessary. Its weight is then determined and a 2- to 5-gm. sample weighed out in a small evaporating dish; over this is poured from 60 to 70 c.c. 20 per cent. sulphuric acid and the dish placed on the water-bath for from one-half to one hour. The resulting digest is then transferred to a 100-c.c. volumetric flask, cooled and made up to the mark with 20 per cent. sulphuric acid. From this two 5-c.c. samples are pipetted into large jena glass test tubes, and 1 gm. potassium sulphate, two drops 10 per cent. copper sulphate and a small pebble added to each. No sulphuric acid need be added as enough is contained in the samples. The tubes are then placed over micro-burners and from this point the determination is carried on as in the method for urine. The digestion mixture should be boiled carefully at first in order to avoid driving it very far up the sides of the tubes. Digestion will be found to be complete in 20 or 25 minutes. One point which is not quite satisfactory must be mentioned. The preliminary digest often contains minute particles which tend to settle, and for this reason the mixture must be shaken immediately before pipetting the samples. All danger of error may be avoided by carrying out the perliminary digestion in a small Kjeldahl flask over a flame, and this plan must be followed when the stool contains casein curds. It has been found, however, that duplicates from the usual type of stool, digested on the water-bath, are in close agreement, and also agree with the result obtained by carrying through a sample by the regular Kjeldahl method. While no essential advantages can be urged, it will be found that as compared with the usual method of doing Kjeldahls this modification is shorter and less cumbersome, and where other colorimetric nitrogen determinations are being carried out at the same time, it fits conveniently into laboratory routine. The micro-method can also be very conveniently used for determination of total nitrogen in milk, in which case no preliminary digestion is necessary. The milk is simply diluted until 5 c.c. will contain about 1 mg. of nitrogen.

Following digestion water is added, then an excess of alkali (3 c.c. sat. sol. of NaOH) and the liberated ammonia is removed by a rapid air current and caught in 20 c.c. of ammonia-free water plus 2 c.c. N/10 HCl. Nesslerize and read in colorimeter.

2. *Ammonia Nitrogen.*—Modification[144] of the aeration method of Folin. Folin and Denis have employed this method occasionally for the determination of ammonia in feces in the course of animal experiments. The steps are very simple. A 1- or 2-gm. sample of well-mixed stool is weighed out on a small bit of oiled paper. The paper and sample are then dropped into a large test tube, and about 5 c.c. of water added. If the stool is fluid, it is weighed in a small porcelain dish and rinsed into the test tube with 5 c.c. of water. A few drops of kerosene and 1 or 2 c.c. of a solution containing 15 per cent. potassium oxalate and 15 per cent. potassium carbonate are then added and the determination carried on as in the method for urine, except that the air current is allowed to run 30 minutes instead of 10. All determinations are made in duplicate and the results averaged. Gamble found that in most of the stools examined by him the agreement between duplicates was within 3 per cent. Considering that the samples were small and weighed separately on an ordinary inexpensive balance, such a result is satisfactory, and is interesting as showing the very uniform composition of the usual type of infant's stool. Stool containing casein shreds and curds gave a difference between duplicates of from 5 to 10 per cent.

3. *Urea Nitrogen.*—Urease method of Marshall, as used by Van Slyke, Courtney and Fales.[448] Forty to fifty grams of fresh feces emulsified in water and diluted to 200 c.c. mixture is made homogenous by grinding in a mortar. Ten cubic

centimeters are placed in a 100-c.c. test tube with 5 c.c. of 0.6 per cent. KH_2PO_4 and 1 c.c. of 10 per cent. "Arlco-urease." After 15 minutes allowed for hydrolysis of the urea, from 8 to 10 gm. of potassium carbonate are added and the ammonia aerated into fiftieth-normal acid. The increase in ammonia resulting from the action of urease represents the urea nitrogen

4. *Free Amino-acid Nitrogen.*—Nitrous acid method of Van Slyke.[448] To 100 c.c. of emulsion (see "*Urea Method*") about 0.5 c.c. of charcoal is added, and the solution is filtered without washing the residue. The volume of the filtrate is measured, and to it 10 per cent. metaphosphoric acid is added until all the protein is precipitated. The volume of metaphosphoric acid solution required is 15 c.c. or less. After a half hour has been allowed for complete precipitation of the proteins, the mixture is made up to a convenient volume, made alkaline by addition of powdered calcium hydroxide, and filtered. The filtrate is free from protein, as indicated by the biuret test. The filtrate is measured and evaporated to dryness on a water-bath. During evaporation the solution, made alkaline by the above-mentioned addition of lime, entirely loses its ammonia. The foregoing treatment therefore frees the solution of both protein and ammonia. The dry residue is taken up with 1 c.c. of 50 per cent. acetic acid and washed into a 10 c.c. measuring flask with small portions of water. Two cubic centimeters portions are used for determinations of ammonia nitrogen by the nitrous acid method.

5. *Total Amino-acid Nitrogen after Hydrolysis of the Proteins* (*Van Slyke*[448]).—Ten cubic centimeters of the feces suspension (see "*Urea Method*") are mixed with 10 c.c. of concentrated hydrochloric acid, and the solution, in a loosely stoppered tube, is immersed in a water-bath at 100 degrees for 24 hours. This assures practically complete hydrolysis of the proteins present. The solution is evaporated to dryness on the water-bath to remove the hydrochloric acid. The residue is taken up with water, made alkaline with calcium hydroxide, and filtered. The alkaline filtrate is concentrated to dryness to remove the ammonia. It is then redissolved with the help of 1 c.c. of 50 per cent. acetic acid; the solution is made up to 25 c.c., and 2-c.c. portions are taken for determination of amino-nitrogen.

Ammonia Nitrogen.—Previous to the recent work of Gamble and Van Slyke but few observations had been made upon the ammonia of the stools and the few quantitative estimations of ammonia were made with what would now be regarded as very inferior methods. Nevertheless Bartling[30] had discovered that the ammonia which could be driven off from a moist sample of human feces by addition of soda varied with the amount of protein in the food. For example, he placed a subject first on a vegetarian diet, next on a mixed diet and finally by addition of nutrose on high protein. The relation of ammonia to total nitrogen in the urine did not change but when the total nitrogen in the feces rose on account of the high protein feeding to double what it had been in the first period the ammonia was trebled. Addition of fat (butter) appeared to be without influence on the fecal ammonia.

Experiments carried out by Gamble show that as much as 15 to 20 per cent. of the total nitrogen of a stool may be lost by escape of ammonia in the process of drying. He believed this ammonia is not all preformed, nor is it produced by bacterial action during the process of drying, but seems rather to be set free from some compound, possibly urea. At all events it is obviously necessary to deal only with fresh stools. Gamble's results from fresh feces (preserved on ice) passed by babies which were "practically normal" are summarized in the following table.

TABLE 54.—AVERAGE AMOUNTS OF AMMONIA IN INFANTS' STOOLS (GAMBLE)

Observations	Protein, grams per kilogram in food	Grams carbohydrate per kilogram in food	Nitrogen in stools		Ammonia nitrogen in stools		Ammonia nitrogen: Total nitrogen, per cent.
			Total Mg	Per gram dried stool, Mg	Total Mg	Per gram dried stool, Mg	
6	1.9	13	341	42	23	2.8	7.4
11	3.9	13	362	40	33	3.6	9.3
13	5.5	11	432	45	42	4.4	9.5
7	8.6	11	673	76	50	6.2	8.4
—	—	—	—	—	—	—	—
37 Grand average.....	5.0	12	443	52	38	4.2	9.0

There is very evident in these results a tendency to parallelism between total nitrogen in the food (also in the feces) and the ammonia formed in the stool. There was no relation to the number of stools passed in a day. The total range was from 1.9 to 15 per cent. of the total nitrogen. In cases suffering from indigestion and malnutrition, including atrophy, Gamble noted much higher quantities both per gram of dried stool and in relation to total nitrogen. Van Slyke and his collaborators found an even higher range, namely, 4 to 37 per cent. of the total nitrogen. The fact that the ammonia nitrogen usually equals or exceeds the amino-acid nitrogen is cited by these

TABLE 55.—AMINO ACID AND AMMONIA NITROGEN IN INFANTS' STOOLS (VAN SLYKE, COURTNEY AND FALES)

Case	Condition	Date	Stools				Acidity cubic centimeters N/100 NaOH
			Grams Total N per gram dried weight bottle fed	Per cent. of total N as			
				Free NH_2	NH_2 after hydrolysis	Free NH_3	
E. V.	Convalescent from diarrhea, constant food.	Nov. 6	0.053	8.4	49.0	4.7	3.74
		Nov. 7	0.058	6.8	52.5	4.3	3.97
5½ mo.		Nov. 8	0.054	3.3	49.7	3.6	2.57
		Nov. 9	0.051	7.2	50.0	5.2	7.92
		Nov. 10	0.051	6.6	47.7	7.6	7.95
		Nov. 11	0.073	4.8	43.4	6.9	3.13
		Nov. 12	0.071	1.8	46.9	8.1	0.0
E. W. 12 mo.	Convalescent, from pneumonia gaining weight, food constant.	Dec. 19	0.052	10.7	41.4	12.8	7.59
		Dec. 20	0.059	13.8	45.6	9.0	10.72
		Dec. 21	0.054	13.6	50.5	12.6	10.15
			Breast fed				
G. R.	Normal..............	Dec. 22	0.046	2.7	49.7	5.2	15.16
4 mo.							
A. R.	Marasmus						
5 mo.	Gaining slightly.......	Jan. 29	0.046	6.2	50.6	7.8	14.59
J. D.	Marasmus............	Jan. 20	0.065	6.3	47.6	5.9	9.65
3 mo.	Gaining slightly........	Feb. 2–5	0.059	6.4	47.4	3.8	10.65

observers as evidence that the ammonia is of bacterial origin. For when animal proteins like casein are split by acids or by aseptic digestion with trypsin the ammonia nitrogen is less than one-seventh the free amino-acid nitrogen. From the theory that fermentative and putrefactive bacteria are antagonistic it might be expected that the ammonia would bear some definite relation to the acidity of the feces; but as may be seen from the above Table 55 this is not the case. In fact there is a coincidence of values oftener than a reciprocal relationship. Nevertheless ammonia may be looked upon as a measure of putrefaction in the colon. There is no evidence that it is excreted by the gut except in extreme stages of diabetes and nephritis. It rises with the protein content of the food and is especially high in intestinal disorders.

Urea Nitrogen.—No great importance need be attached to this fraction of the nitrogen until it is definitely shown to be a constituent of the feces. Gamble found urea in all of the stools examined by him, and he evidently believed there had been no contamination with urine. Moreover he points to the increase in urea when the stools were kept standing for several days at room temperature as proof that this product can be formed by bacterial action. Van Slyke on the other hand is very positive that urea was not present in at least 19 out of 25 stools examined.

The average amount found by Gamble was 13 mg. for a 24-hour period, or 2.0 mg. per gram of dried stool, which made 3.5 per cent. of the total nitrogen. Van Slyke reports only 0.3 to 3.0 mg. per gram of dried stool or from 1 to 5.6 per cent. of the total nitrogen.

Amino-acid Nitrogen.—While it is certain that bacteria can produce free amino-acids from proteins the presence of them in the feces cannot be taken as a measure of putrefaction; for on the one hand, putrefaction usually proceeds rapidly beyond this stage to the formation from the aromatic amino acids of the characteristic phenols and on the other amino-acids formed by the digestive enzymes may well escape absorption. Van Slyke (Table 55) from his few analyses believed that the more watery the stools were, *i.e.*, the quicker had been the passage through the alimentary tract, the larger was the proportion of total nitrogen in the form of amino-acids. There was a wide variation (from 1.8 to 17.6 per cent.) of the total nitrogen in this form.

Higher Forms of Nitrogen.—As shown in Table 55 the extra NH_2 nitrogen set free by hydrolysis of the stool made up a fairly constant proportion of the total. Some of this higher nitrogen certainly is present in the form of albumoses,[6] peptones, and peptids, but there remains a considerable fraction over as true protein. Since it has been shown[444] that most animal proteins upon hydrolysis yield about 75 per cent of their nitrogen as free NH_2, amid nitrogen and nitrogen of prolin, oxyprolin, tryptophan, arginin, and histidin which have all or part of their nitrogen in other form than NH_2, by multiplying the amount of amino nitrogen found after acid hydrolysis by 1.33 we obtain the amount of nitrogen present originally as protein and proteolytic products. Van Slyke applied this factor and found that 60 to 70 per cent. of the nitrogen in infants' stools as they are passed is present in the form of protein bodies from the grade of amino-acids upward. The free amino-acids make up from 2.4 to 24 per cent. of this total while higher cleavage products and proteins make up the rest. The protein of the alimentary secretions, the unabsorbed enzymes, mucin and the nuclein of the stool would be numbered among the unchanged proteins.

The only work on the feces of adults with which the results of Gamble and Van Slyke on infant's stools can be compared is that of Eppinger and Gutmann,[116] who in the course of a study on the causes of intestinal intoxications made a partition of the fecal nitrogen in two normal subjects on mixed diet. Their results as given by Schmidt and Strasburger[392] follow:

Table 56.—Distribution of Nitrogen in Human (Adults) Feces (Eppinger and Gutmann)

Subject	Total nitrogen	NH_3N	Basic nitrogen	Urea nitrogen	Mon-amino-acid nitrogen	Per cent. of total nitrogen			
						NH_3	Basic nitrogen	Urea nitrogen	Mon-animo-acid nitrogen
I	35.5	19.0	0.5	15.0	0.5	54.0	1.4	43.0	1.4
II	45.5	19.0	9.0	15.0	2.5	41.7	19.8	33.0	5.5

The enormously greater percentages of ammonia and urea nitrogen than in infant's stools doubtless reflect the greater degree of putrefaction in the adult colon.

Nitrogen of Curds.—Curds may be mentioned in this place merely as a form in which nitrogen may occur normally in infant's stools. The disposition which previously existed among pediatrists to regard everything of the appearance of curd in the stools of artificially fed infants as distinctly abnormal and pathognomonic of disordered digestion has given way to the view that small or even large clumps of casein may exist in the stools without any sign of disorder,[80] that they are mechanically formed by some peculiarity of evacuation from the stomach[82] and that they are prevented effectually by the simple expedient of boiling[56] the milk. Talbot[418] has analyzed both the small, soft and the large hard curds, and found that the former have a normal (for feces) percentage of nitrogen and a high percentage of fat while the latter have a high percentage of nitrogen (casein) and a low percentage of fat. Counting the protein content of the hard curds at 65 per cent. Courtney[80] calculated that the total loss of protein occasioned by their formation in the stools was from 0.06 to 0.95 gm. in 24 hours.

Bacterial Nitrogen.—Methods for the separation of the fecal bacteria and estimation of the nitrogen contained therein have been in use for the past two decades; but so far as the writer can learn they have not been applied to the normal infant. Strasburger[415] found that on a moderate mixed diet the adult may pass as much as one-half of the fecal nitrogen in the form of bacteria, and this figure has been slightly increased by Mattill and Hawk[283a] using a more exact method of separation. In cases of infantilism McCrudden and Fales[292] found from 3 to 33 per cent. The relative losses of total nitrogen under the influence of putrefactive as against a fermentative flora in infancy and the distribution of nitrogen under the two conditions would seem to be a subject worthy of investigation.

Utilization of Fats.—The quantitative determination of fat in the feces of infancy is even more important than is that of the nitrogen. As in the case of nitrogen some of the fat always has its origin in the body itself from the intestinal secretions and some of it from the food. In the feces of the professional fasters Cetti and Breithaupt, Fr. Müller[313] found 1.2 and 0.57 gm. of fat daily. In the single infant studied by Keller (p. 741) after feeding "protogen" which contained no fat, there was a daily elimination of 0.0276 gm. fat and fatty acid, while in the adult, as Van Noorden[443] has shown, it may happen with a very low intake of fat that the fecal fat actually exceeds the fat in the food. This can scarcely ever be the case with the infant.

Regarding the nature of the fat in the feces it has been claimed by a number of observers[312] that on account of the more ready digestibility of fats containing the lower fatty acids, the higher fats predominate giving a higher melting point of some 8°C. above the food fat. Hecht[176] on the other hand maintains that this can scarcely be true of the infant, for even the very small difference in olein content of mother's and cow's milk is discernible in the stools. Cowie and Hubbard[82] support the view that a physical change takes place in the fat while passing through the alimentary tract with the following observation. "Before ingestion a centrifugal test shows a clear fluid, yellow, fat layer which becomes more firm as it cools. It remains however in this clear condition and is easily read on the scale. After the milk passes through the digestive tube a centrifugal test shows a denser and darker fat layer which solidifies at a higher temperature and contracts in such a way as frequently to cause it to break in the center. If the tube is immersed in hot water the fat column melts and again occupies its former position in the tube. There is evidently a change in the specific gravity of the fat after it has passed through the intestine."

So much depends upon the method chosen for the estimation of fat in the feces and the methods have been improved so much in recent years that most of the older observations upon utilization can not be compared with modern work. Nevertheless a few of those made previous to 1910, summarized by Freund[137] and vouched for as to reliability by him may be given. All those presented were healthy infants fed on cow's milk.

TABLE 57.—UTILIZATION OF FAT IN ARTIFICIALLY-FED HEALTHY INFANTS (FROM FREUND)

Author	Age	Body weight	Food	Food fat	Fecal fat	Per cent. utilization
Keller	2¾	4900	⅔ milk	6.77	0.22	96.7
Rubner and Heubner	7½	....	whole milk	33.3	1.16	96.5
L. F. Meyer	3	5750	whole milk	25.56	0.74	97.1
L. F. Meyer	3	....	whole milk	25.58	0.26	99.0
Birk	4½	3930	Milk, barley	9.31	1.99	78.0
Birk	9	5600	Milk, malt barley	14.21	1.1	92.2
Birk	10½	5990	Milk, malt barley	14.33	1.17	91.9

With a single exception the utilization is above 90 per cent. Freund's complete table which includes studies made upon bottle-fed babies suffering from various types of alimentary and constitutional disorders, shows that the utilization is very rarely lower than this figure under any circumstances.

Turning now to more modern results it will be of service to describe briefly the methods which have been worked out in this country both for rapid clinical examination of the stools with reference to total fat and at least one method for the separation of fecal fat into its most important fractions; namely, soaps, free fatty acids, and neutral fat. For special constituents like the volatile fatty acids, cholesterol cholic acid, etc., other methods[392] must be employed.

Rapid Methods for Determination of Fat in Stools. (1) *Centrifugal Method of Cowie and Hubbard.*[82] The Sample.—If pulverized stool is examined, one-quarter (0.25) gram should be carefully weighed. If fresh or moist stool is examined, one-half (0.5) gram. An inexpensive prescription balance is sufficiently accurate for clinical purposes. For more careful work an analytical balance is of course necessary. The stool, if dry, is best weighed in a poised watch glass and transferred to glazed paper. Moist stool is quite easily removed by means of spatula from glazed paper on which it is weighed, or from the watch glass, by means of water. The sample is carefully rubbed up in a thin-lipped mortar. A maximum of 20 c.c. of warm (40 to 50°C.) distilled water is used to transfer the mixture to a Babcock milk bottle graduated in fiftieths. A little practice enables one to transfer the entire sample with the first 10 c.c. of water, leaving the remainder to rinse off the mortar and pestle.

1. To the sample, now thoroughly mixed 17.5 c.c. H_2SO_4 (1.84) is added. Great care should now be taken to mix thoroughly by shaking the bottle back and forth vigorously (it should be remembered that all the organic material except the fat must be completely burned, or the test will be a failure).

2. One cubic centimeter amyl alcohol is now added and thoroughly mixed.

3. The tube is now carefully counterpoised and centrifugalized for three minutes at high speed. Enough hot water is then added to bring the fat into the graduated portion of the stem of the bottle. The bottle is again counterpoised, centrifugalized for one minute and the number of divisions on the stem occupied by the fat read off. Care must be taken to keep the stem hot and all readings must be made while it is hot. This is quickly accomplished by immersing the bottle in a pitcher or beaker of hot water.

Calculation.—If 0.25 gram of stool has been used, multiply the number of divisions on the stem of the tube occupied by the fat column by the factor 7.2; if 0.5 gram sample of stool is used, multiply by the factor 3.6; the result is the percentage of fat in the sample examined.

To determine the amount of fat in the 24-hour sample of stool, the stools may either be weighed when passed, or they may be kept in a moist chamber and weighed at the end of the period. The former is the better method for, by this means any loss or gain in weight may then be detected and accounted for. The stool from which the sample is taken must be thoroughly mixed. From the known weight of the stool the total amount of fat is readily estimated. With a little practice a complete test can be made in ten minutes.

According to the authors this method is not subject to as many errors as the extraction method of Folin and Wentworth, and it gives more concordant results.

2. *Nephelometric Method of Laws and Bloor.*[261] *Procedure.*—The whole stool is weighed to centigrams on a previously weighed porcelain plate and then thoroughly mixed with a spatula. A dry and clean 100-c.c. graduated Erlenmeyer flask, together with an 8-cm. filter paper is weighed to milligrams. About 0.5 gm. of the mixed stool is spread out in a thin and even layer on the filter paper, then the paper and flask weighed again. The difference between this weight and the original weight of flask and filter paper is the amount of stool taken.

To the flask are added 60 to 70 c.c. of a mixture of three parts redistilled alcohol and one part redistilled ether, and five drops of concentrated hydrochloric acid. The filter paper should be entirely immersed in the liquid. The flask is connected with a return condenser and boiled for 45 minutes, then cooled under the tap with shaking and made up to volume with alcohol-ether, mixed and filtered. The filtrate is usually water clear, but may have a slight tinge of green or brown.

Determination.—Five cubic centimeters of the extract are measured from a pipet, with stirring, into a small beaker containing 50 c.c. of distilled water. To the standard and to the test solutions are added simultaneously 10 c.c. portions of dilute (1:4) hydrochloric acid with stirring. The solutions are allowed to stand for five minutes, after which they are transferred to the comparison tubes of the nephelometer.

The two tubes are filled to the same height with the solutions and are placed in the nephelometer with the standard tube always on the same side. (If bubbles appear on the walls of the tube it is important that they should be removed by inverting the tube two or three times. At the end of the readings again examine the tubes for bubbles and if they are present the tubes should again be inverted and another reading made.) The movable jacket of the standard is usually set at 50 mm. (on the original Richards Nephelometer) or at 30 mm. in a modified Duboscq colorimeter as described by Bloor. The comparison is made by adjusting the jacket of the test solution until the illumination of the solutions are equal. At least five readings are taken alternately from below and above and the average taken as the correct reading. The readings are inversely proportional to the values, and calculations are made as in the colorimetric methods.

Standard Solution.—The standard solution used is an alcohol-ether solution of equal parts of pure stearic and oleic acids, of which 5 c.c. contain 2 mg. of fat. Equal amounts give readings closest to the results obtained by the Folin-Wentworth and the Kumagawa and Suto methods.

The nephelometric method as above will give consistent results to within 5 per cent. of the results obtained by the older methods, and is therefore adequate for all clinical purposes.

In the authors' hands this method gave results which were usually within 3 per cent. of the Folin-Wentworth method.

Distribution Method of Roese and Gottlieb,[344] as modified by Holt, Courtney and Fales.[200] *Procedure.*—One-gram samples of thoroughly dried and powdered material are weighed into small evaporating dishes. One-half of these samples are used for the determination of total fat and the other half for determination of the unsaponified fat; that is, the neutral fat and the free fatty acids. To each sample which is to be used for the determination of total fat there is added about 10 c.c. of dilute hydrochloric acid (one part of concentrated hydrochloric acid to three parts of water) and to those which are to be used for the determination of the unsaponified fat there is added the same volume of water; that is, about 10 c.c. The dishes are then placed on a water bath and left there until contents are thoroughly heated and disintegrated. The homogenous mixture from each dish is then transferred to a Röhrig tube and washed in, first with sufficient water to bring the contents of the tube exactly to the mark designating half the capacity of the portion below the faucet, then with 95 per cent. alcohol until the tube is filled to the level of the faucet. There is then added 25 c.c. of ethyl ether, free from non-volatile matter, and the tube is shaken vigorously for a half a minute; there is then added 25 c.c. of petroleum ether (boiling below 60°C.) and the tube is again shaken for a half-minute. The mixture is allowed to stand until the upper liquid is perfectly clear. The layer of ether containing the extracted fat is then drawn off by the faucet through a quick-acting filter paper into a bottle of known weight. To make the extraction complete the process is repeated with 20 c.c. of both kinds of ether, For extreme accuracy a third extraction is made with 30 c.c. of the mixed ether, which has been recovered from previous determinations. To insure against loss of fat, the tip of the faucet, the funnel and filter paper are washed with about 10 c.c. of mixed ether.

The ether is distilled from the combined extracts by means of an electric stove. The distillate, composed of mixed ethyl and petroleum ether, is condensed and used for further determinations. The fat residue is dried over night on a water bath, then for several hours in an oven 98°C., desiccated and weighed.

In order to determine the free fatty acids the extract from the non-acidified samples is used. After the fat has been dried and weighed, it is dissolved in benzol, heated and titrated while very hot with tenth-normal alcoholic sodium hydrate. Phenolphthalein is used as an indicator and the titration is carried to the maximum color. The alkali used is standardized by stearic acid, dissolved in hot benzol.

The difference in weight between the extract from the acidified material (the total fat) and that from the non-acidified material (the neutral fat and free fatty acids) is the weight of soap fat. The difference between the weight of the non-acidified extract and the weight of the free fatty acids, computed from titration figures, represents the neutral fat. The following is an example:

(*A*)	Weight of extract from acidified sample	0.38 gms.
(*B*)	Weight of extract from nonacidified sample	0.24 gms.
	Difference between *A* and *B*. Fat as soap	0.14 gms.
(*C*)	Titration of *B*	6.0 c.c.
	Equivalent weight of free fatty acid	0.17 gms.
	(1 c.c. tenth-normal NaOH = 0.0284 gm. stearic acid)	
	Difference between *B* and *C*. Neutral fat	0.07 gms.

By means of the last named method a very important series of observations has been carried out by Holt and his assistants on a wide range of subjects. In the first study[201] on fat in the stools of breast-fed infants they set themselves the following questions: (1) What is normally the per cent. of total fat and what is the distribution of fat as soap, free fatty acids and neutral fat in the stools of healthy breast-fed infants? (2) What is the difference in fat content and distribution of fat between normal and abnormal stools? (3) Does the amount and distribution of fat in the stools of healthy breast-fed infants vary with the per cent. of fat in the milk and with the amount of fat intake?

Thirty-four different infants ranging from 10 days to 10 months of age served as subjects. Thirty of them were well-nourished and with few exceptions were gaining normally. In the majority of the infants the authors state that "the appearance of the stools was typical of normal breast-fed infants, largely yellow, granular or pasty, very acid to litmus, with acid, aromatic, not unpleasant odor." A number of the children however had distinctly abnormal stools being markedly green and containing much mucous.

The following table gives a summary of the analyses:

TABLE 58.—AVERAGES OF TOTAL FAT AND FAT DISTRIBUTION IN STOOLS OF HEALTHY, BREAST-FED INFANTS (HOLT, COURTNEY AND FALES)

Number of stools	Description of stool	Age range	Dry weight fat, per cent.	Percentage of total fat as		
				Soap	Free fatty acids	Neutral fat
15	Normal, yellow	3 weeks to 6.5 months	42.1	57.8	26.3	15.9
15	Partly green, some mucous	4 weeks to 5 months	36.6	33.1	47.2	19.7
13	Entirely green, much mucous	6 weeks to 10 months	23.0	37.7	36.7	25.6
Grand average			34.5	43.1	36.7	20.2

The most noteworthy differences are the much higher free fatty acids of the second group and the low total fat in the third. The latter is explained by the presence of a large amount of mucous. Since this type of stool is usually an indication of an abnormal intestinal condition accompanied by a larger total excretion of feces the total daily

TABLE 59.—UTILIZATION OF FAT BY NORMAL BREAST-FED INFANTS (HOLT, COURTNEY AND FALES)

Case	Age	Intake grams fat daily	Excretion grams fat in feces daily	Per cent. of intake utilized	Condition of child
E. M.	13 weeks	42.5	0.31	99.2	Gaining
J. F.	10 months	33.0	0.27	99.2	Healthy, gaining; stool green and full of mucous
P. L.	9 weeks	31.1	1.61	94.9	Excellent condition; gaining
P. L.	3 weeks	37.7	1.95	94.8	Excellent condition; gaining
P. L.	3.5 weeks	41.9	2.26	94.5	Excellent condition; gaining
J. M.	4 months	10.6	0.62	94.2	Gaining very little; mother's milk abnormally low in fat and sugar
V. R.	3 months	19.8	1.22	93.9	Well-nourished but not gaining at time of observation
D. T.	6 weeks	9.8	0.94	90.3	Gaining; previously marasmus
Average				95.1	

loss of fat, the authors think, would be greater than occurs in children with normal stools. Table 58 answers the first question (given above) as to the normal distribution. It was found in accordance with the prediction of Folin and Wentworth[132] that when a large composite stool was analyzed first in the fresh state and also after drying that there was a material increase in the percentage of soap at the expense of the free fatty acids, some of which, being volatile, were lost in the process of drying.

The utilization of fat by those children of the entire group whose intake of fat was definitely known is given in Table 59.

In a second study Holt, Courtney and Fales analyzed 128 stools from 77 infants ranging from 2 to 18 months of age, who were fed on modifications of cow's milk. The digestion of the larger number was quite normal; but some were suffering from disturbances of digestion of varying degrees of severity. A summary of these results is given below.

TABLE 60.—AVERAGE TOTAL FAT AND ITS DISTRIBUTION IN THE STOOLS OF INFANTS FED ON COW'S MILK MODIFICATIONS (HOLT, COURTNEY AND FALES)

Type of stools	Number of observations	Intake of fat, grams daily	Analyses of stools			
			Fat, per cent. of dried weight	Per cent. of total fat as		
				Soap	Free fatty acids	Neutral fat
Constipated	19	22.9	36.0	73.8	17.6	9.0
Normal	31	24.0	36.2	72.8	16.5	9.4
Softer than normal	16	21.5	31.9	59.8	24.5	11.9
Not homogeneous	16	16.1	32.7	44.6	19.3	22.5
Loose	12	23.3	30.2	30.6	16.6	55.1
Diarrheal	26	19.5	33.4	12.4	30.4	61.6
Severely diarrheal	8	19.4	40.7	8.8	38.1	56.4

This table supplies the answer, for bottle-fed babies, to the first question which was propounded for the breast-fed infants. It will be noted that the constipated stools have the same average percentage of total fat and of soaps as the normal stools; and that the total fat average is highest for a group which had severe diarrhea.

The distribution of fat varies much according to the type of stool. The high soap values occur among those whose appearance was normal, and the low values among those showing by gross appearance some evidence of digestive disturbance. The falling off of the soaps as the stools become more and more abnormal is accompanied by a compensating increase in the neutral fat. The reason is obvious. The more rapid passage of the contents through the alimentary tract afforded less opportunity for cleavage and for soap formation. The average utilization of fat by these infants is shown in Table 61.

Table 61.—Average Utilization of Fat by Infants Fed on Cow's Milk Modifications (Holt, Courtney and Fales)

Type of stools	Number of observations	Intake of fat, grams daily	Fat in stool, grams daily	Fat retained, grams daily	Per cent. of intake utilized
Constipated	11	27.1	2.74	24.4	89.9
Normal	18	26.7	2.33	24.4	91.3
Softer than normal	14	23.0	2.79	20.2	87.9
Not homogenous	12	19.6	2.16	17.5	89.1
Loose	12	23.3	3.74	19.6	83.9
Diarrheal	22	21.6	4.47	17.1	79.3
Severely diarrheal	7	21.3	8.84	12.5	58.5

The average utilization, even among the subjects whose stools were perfectly normal in appearance, was not quite so good as among the breast-fed. The authors conclude from these studies that there was no definite relationship in either group between the daily fat intake and either the utilization or the distribution of fat to the different fractions. For further information regarding abnormal conditions the original papers should be consulted.

Utilization in Children above One Year.—The third study of Holt and his collaborators was made upon 134 collections of feces from 62 children from one to ten years of age. The larger number of these subjects were in normal condition both as to general health and digestion. Only these will be considered in this connection. They were divided by the authors for the purpose of presentation into three groups: (1) children fed on milk alone or on bread and milk or cereal and milk, whose stools were normal in appearance; (2) children on mixed diet containing a liberal portion of milk whose stools were constipated; and (3) children on mixed diet of the same character whose stools were normal. The average results are concentrated in Table 62 and with them

Table 62.—Average Total Fat and Distribution in Stools of Infants Compared with Older Children (Holt, Courtney and Fales)

Group	Number of stools	Character of stools	Intake of fat, grams daily	Analysis			
				Fat, per cent. dried feces	Per cent. of fat as		
					Soap	Free fatty acids	Neutral fat
Infants on milk modification	30	Normal	24.0	36.2	72.8	16.5	9.4
	19	Constipated	22.9	36.0	73.8	17.6	9.0
Children on milk or milk with bread and cereal	10	Normal or constipated	29.6	30.7	60.9	25.1	14.0
Children on mixed diet	41	Normal	40.5	18.0	45.1	27.4	27.5
	21	Constipated	40.9	20.1	47.9	26.5	25.6

are given by way of comparison the same data for normal infants on cow's milk modifications whose stools were either normal or constipated.

By "normal stool" in the group now under consideration is meant, in the words of the authors, "a stool which was smooth, homogenous, not hard, showing no mucous or undigested foods." The reaction to litmus of the stool as passed was, in the majority of cases, decidedly alkaline; in a few it was amphoteric, but never acid.

Table 62 shows that in both the infants and older children the agreement between "normal" and constipated stools is very close, confirming the idea that constipation is chiefly a question of water content. The ash content was estimated in the normal and constipated stools of the older children and found to be 18.7 per cent. of the dry weight for the former and 19.8 per cent. of the latter. As in the case of the infants fed on milk exclusively, so in the older children there was no change in the relationship between total fat and soaps on the one hand, and total fat and fatty acids on the other, when the stools were dried (p. 757).

The table above shows a marked difference in the distribution of fat to its several fractions in stools from solid or mixed foods as contrasted with stools from milk alone. The percentage of total fat to begin with is only half that in the stools of bottle fed infants, the percentage of fat as soaps is much lower, the fatty acid and neutral fat both higher. In the absence of the absolute data as to the several fractions it is a little difficult to place a satisfactory physiological interpretation upon these differences. By a round-about calculation we can arrive at some of the data needed. Thus since the average utilization in the older children (Table 63) is 94 per cent., the loss of food fat in the feces was (6 per cent. of 41 gm. =) 2.46 gm. daily. In the infants on cow's milk the utilization (Table 61) was 90.5 per cent. and the total loss was (9.5 per cent. of 23.5 gm. =) 2.23 gm. daily. This amount of fat, nearly the same in the two groups, we learn, was roughly 19 and 36 per cent. respectively (Table 62) of the total dry weight. It follows that the total dry weight of feces daily was almost twice as much on the average in the older child as in the infant. The

TABLE 63.—AVERAGE UTILIZATION OF FAT IN CHILDREN ON MIXED DIET COMPARED WITH INFANTS ON COW'S MILK (HOLT, COURTNEY AND FALES)

	Character of stool	Intake of fat, grams daily	Fat in stools, grams daily	Fat utilized, grams daily	Per cent. of intake utilized
Infants on usual milk modifications.	Constipated...........	27.1	2.74	24.4	89.9
	Normal...............	26.7	2.33	24.4	91.3
Children on milk or milk with bread and cereal..	Constipated or normal..	29.6	2.76	26.8	90.6
Children on mixed diet.	Constipated...........	41.2	2.51	38.7	93.9
	Not normal............	40.1	2.38	37.7	94.0
	Normal...............	40.8	2.48	38.3	93.9

low percentage of fat is due in part to the high percentage of other constituents in the feces. However, the total fat is nearly twice as great in absolute terms and the utilization is much better. These two facts indicate that some other factor is responsible for the relatively high elimination of fat in the stool of the infant on milk alone.

Directing attention for a moment to the soaps of the two classes of stools it is found that somewhere in the neighborhood of 1.6 gm. of soap is eliminated daily from an intake of 23 or 24 gm. fat in the infant, while approximately 1.1 gm. are eliminated from an intake of 41 gm. in the older child who has had solid food with the milk. Something may hinge upon the question of the kind of fat which will be discussed a little later. It is learned from Holt's detailed tables, however, that a considerable portion of the extra fat (aside from milk) which was given was butter. Other items which recur frequently in his tables are nut butter, corn oil, and eggs. Quite probably some of these are not so digestible as is the fat of milk. The higher absolute and relative amount of neutral fat in the stool indicates this. But the high fatty acid fraction in the stools of older children together with lower soap fraction means apparently that not so much alkali has been available to the older child for the formation of soaps. We need look no further than the milk itself for the source of this alkali. It is well known that cow's milk carries a high percentage, relative to mother's milk, of calcium present as phosphate and that this calcium in so far as it is soluble can unite with the fatty acids to form insoluble soaps. Holt's table therefore furnishes a good instance of the larger loss of fat in bottle-fed babies, as contrasted with older children receiving other foods, in the form of calcium soaps. In the older child a part of the fatty acids which would be carried out by the calcium, if milk alone had been fed, escaped as such.

Factors Influencing Utilization of Fat.—The question which has just been touched upon is one which has agitated pediatric circles both here and in Europe more or less for the past twenty-five years. In Europe the emphasis was first placed upon the danger of high fat feeding[272] as predisposing to a "relative acidosis," to use the phrase of Stutz, by withdrawal of alkali in combination with fatty acids; while in America warning has been raised against the possible over-feeding of calcium[53] in cow's milk and the consequent interference with absorption of fat by formation of insoluble soaps. The first phase of the matter just mentioned may be deferred for discussion under the topic of "ammonia in the urine" with which it is more intimately connected But the influence of calcium on the utilization of fats is one which should be disposed of here.

1. *Calcium.*—Hecht[177] raised the alarm concerning the danger of excessive losses through the formation of insoluble soaps in connection with an investigation on the "milk food-injury" of Czerny. His idea was that a continuous output of soapy stools betokened a low-grade, but always chronic disturbance to the absorption of fat. Bahrdt[25] in taking up the question a couple of years later after making careful

analyses by means of the Kumagawa-Suto method arrived at the viewpoint that the relation of neutral fat to soap-fat not only was disturbed, but there was even an increase in the elimination of total fat. Several other observers[138,139] using equally good methods found on the contrary that the utilization was just as good or nearly so as in normal stools. Niemann[326] indeed with 39.7 gm. fat in the food of an infant and in spite of a large amount of fecal fat (63 to 66 per cent.) in the form of soap observed a utilization of 96 per cent. Impressed with the findings of their exhaustive analyses of the mineral constituents of milk, which are given in Table 64, Bosworth and Bowditch have drawn attention to a slightly different aspect of the matter. Notwithstanding the high calcium content of cow's milk the calcium metabolism of the infant fed with it, measured by the Ca present in the urine, is "seldom greater and often is less than that found in breast-fed infants," most of the calcium being eliminated in the feces as insoluble phosphate and soaps. In so far as calcium is already insoluble as the diphosphate it is of no use to the infant. But in so far as it is already soluble, as caseinate, or is rendered soluble by action of the hydrochloric acid of the stomach, it is a menace in that: (1) it removes phosphate of exogenous (food) or endogenous (alimentary secretions) origin; (2) it ties up with fatty acids as insoluble soap and thereby prevents absorption to this extent; and (3) if still in excess, it enters the circulation and has toxic effects. The authors present a table showing that the elimination of calcium soaps in the stools increases directly in proportion to the degree of solubility of calcium in the food and in the case of foods containing calcium caseinate or the caseinate plus acetate the urine is rendered phosphate free.[53] As evidence of the toxic effects of calcium the authors offer the following experiment.[55] Feeding a large amount

Table 64.—Forms in Which Mineral Elements are Present in Milk

Organic	In 100 c.c. cow's milk, grams	In 100 c.c. human milk, grams
S. with casein and albumin	0.022	0.001
P. with casein and albumin salt combination	0.022	0.001
Ca. combination with protein	0.054	0.024
Di. Ca. phos. $CaHPO_4$	0.175	0.000
Mono. mag. phos. $MgH_4P_2O_8$	0.103	0.027
Di. potas. phos. K_2HPO_4	0.230	0.000
Mono. potas. phos. KH_2PO_4	0.000	0.069
Potas. citrate $C_6H_5O_7K_3$	0.052	0.103
Sod. citrate $C_6H_5O_7Na_3$	0.222	0.055
Ca Cl_2	0.119	0.059
Iron	trace	trace
Total salts	0.955	0.337

of para-casein (containing calcium as caseinate) with cream and lactose but without the salts of whey produced a temperature of 102.4°F. accompanied by lactic acid in the urine and increased elimination of creatin and uric acid indicating katabolism of tissue. The toxic condition is explained as follows. "The digestion of fat and protein within the intestine results in the production of acids, fatty acids from fat and amino-acids or polypeptic acids from the proteins. These acids do not remain as free acids but immediately unite with the bases present in the intestine to form salts, the soluble salts being absorbed, the insoluble salts being eliminated in the feces. In the presence of the large amount of calcium carried into the intestine in combination with the casein many more of these acids form calcium salts than would be the condition under more normal circumstances. The soluble organic salts are carried to the tissues and the organic part used for vital activities leaving as refuse the base calcium which has acted simply as a conveyor and neutralizer. Under normal conditions this calcium would form chlorid or phosphate and be eliminated in the urine immediately. Under the conditions of this experiment there was no chlorin available for such purpose and very little phosphorus. The result is an accumulation of calcium until a toxic condition is reached and then, during the fever, an abundant elimination of soluble calcium lactate." In this way is accounted for the toxic effects of high protein feeding in the absence of whey salts in experiments reported by Holt, Levene and others,[196] in which a temperature of 105.2°F. was produced together with other toxic symptoms. The beneficial effect of Finkelstein's protein milk is explained on the ground that the mineral content approximated very closely both in amount and form the mineral content of breast milk. In order to feed high fat without harmful effect Bosworth and Bowditch recommend the use of a "reconstructed milk" with a much lower percentage calcium. While the danger of high protein feeding without whey salts may be accepted upon the physiological grounds urged by Bosworth and Bowditch, there seems to be no doubt that they, like Hecht and others, have magnified the injury which may result from loss of insoluble soaps by feeding ordinary modifications of cow's milk. Holt, Courtney and Fales,[199] like Freund, Niemann and others are able to point to numerous instances (p. 761) of fairly high fat intake followed by elimination of a high percentage of soap in the stools, but where there was nevertheless a very satisfactory utilization. Furthermore in experiments directed expressly to the purpose Holt[205] demonstrated that in normal, bottle-fed infants there is no constant relation between the excretion of total fat and the excretion of calcium in the stools. The calcium excretion is much more closely related to calcium intake than to the excretion of soap. Fife and Veeder[119] had reached the same conclusion in their study of fat utilization in atrophic infants. In cases of very poor utilization of fats such as were obtained by Givens[152] in feeding ethyl palmitate and unneutralized palmitic acid to dogs the output of calcium by the feces, as would be expected, may be very considerably increased.

2. *Kind of Fat.*—Another factor in the utilization of fat is the nature of the fat itself. Arnschink[21] many years ago published experiments on dogs showing the effect of melting point upon digestion and utilization of fats which Van Noorden[443] used to calculate the probable fecal losses from the different pure fats in human metabolism. The table follows:

TABLE 65.—INFLUENCE OF MELTING POINT ON UTILIZATION OF FATS (ARNSCHINK)

Kind	Melting point	Per cent. lost in feces
Stearin	60°C.	86–91
Mixture of stearin and mandel oil	55°C.	10.6
Mutton fat	52°C.	7.4
Lard	43°C.	2.6
Pork fat	34°C.	2.5
Goose fat	25°C.	2.5
Olive oil	fluid	2.3

It is well known that the fat of milk is a mixture of a large number of different simple fats. The analysis by C. A. Brown[57] presented in Table 66 enumerates the fatty acids found, gives their relative melting points, molecular weights, and empirical formulæ, besides the relative amounts of each.

TABLE 66.—AMOUNTS OF FATTY ACIDS OBTAINED BY SAPONIFICATION OF 100 GM. BUTTER (C. A. BROWN)

Name	Formula	Molecular weights	Amounts, grams	Melting points, Centigrade
Dioxystearic acid	$C_{18}H_{36}O_4$	316	1.00	136.0
Oleic acid	$C_{18}H_{34}O_2$	282	32.50	14.0
Stearic acid	$C_{18}H_{36}O_2$	284	1.83	69.2
Palmitic acid	$C_{16}H_{32}O_2$	256	38.61	62.0
Myristic acid	$C_{14}H_{28}O_2$	228	9.89	54.0
Lauric acid	$C_{12}H_{24}O_2$	200	2.57	43.6
Capric acid	$C_{10}H_{20}O_2$	172	0.32	31.4
Caprylic acid	$C_8H_{16}O_2$	144	0.49	16.0
Caproic acid	$C_6H_{12}O_2$	116	2.09	2.0
Butyric acid	$C_4H_8O_2$	88	5.45	2.0

In the light of this table it is interesting to learn from the analyses of Bosworth, Bowditch, and Giblin[53] that the acid found upon saponification of the fat in the soapy stools of normal infants fed upon modifications of cow's milk is made up almost exclusively of oleic and palmitic acids, the acids which are present in largest amount in perfectly fresh butter. In an analysis they found out of a total of 12.3 gm. of fatty acids, 2.9 gm. or 23.6 per cent. of oleic acid and 9.4 gm. or 76.4 per cent. "almost pure" palmitic acid. With this distribution of fats in the feces as against a much larger proportion of oleic acid in butter it is clear that the mixed fat does undergo a change in physical character while passing through the alimentary tract (p. 754).

Recently an extensive study[204] of the influence of vegetable fats, used in varying proportions in the food, upon the general character and composition of the feces of children receiving mixed diet, has given the following results (Table 67). The fat percentage of dried weight of the stools averaged somewhat lower when nut butter was taken and somewhat higher when corn oil was taken than when the fat consumed was mainly milk fat. When large quantities of corn oil were given the average was considerably higher. Along with this went a slightly higher percentage of soap. When vegetable fat formed a considerable part of the total fat intake the percentage of fat utilized was usually higher than the normal average.

TABLE 67.—COMPOSITION OF FAT IN STOOLS AND FAT UTILIZATION OF CHILDREN RECEIVING MILK FAT WITH THAT IN CHILDREN RECEIVING VARYING PROPORTIONS OF CORN OIL AND OF NUT BUTTER (HOLT *et al.*)

Fat in diet	Reaction of stools	Analyses of stools				Utilization of fat			
		Fat, per cent. of weight	Percentage of total fat			Total fat in feces, grams daily	Intake of fat, grams daily	Fat utilized, grams daily	Per cent. of intake retained
			Soap	Free fatty acids	Neutral fat				
Fat mostly as milk or butter	Alkaline....	18.0	45.1	27.4	27.5	2.48	40.8	38.3	93.9
	Acid.......	15.1	32.8	31.3	35.9	2.38	40.1	37.7	94.0
20 to 35 per cent. fat as nut butter.	Alkaline....	14.7	36.3	29.7	34.0	1.71	39.1	37.4	95.7
	Acid.......	19.4	35.8	27.7	36.5	3.17	43.2	40.0	92.6
35 to 70 per cent. fat as nut butter.	Alkaline....	14.1	42.2	28.4	29.4	2.23	43.1	40.9	94.9
	Acid.......	19.4	39.1	41.7	19.2	2.61	58.5	55.9	95.6
35 to 70 per cent. fat as corn oil....	Alkaline....	20.6	38.9	29.4	31.7	3.23	61.4	58.2	94.6
70 to 95 per cent. fat as nut butter.	Alkaline....	13.9	38.2	26.6	35.2	1.93	39.9	38.0	95.2
70 to 95 per cent. fat as corn oil.	Alkaline....	31.7	30.3	36.0	33.7	4.80	56.2	51.4	91.5

3. *Other Foods.*—Several observers[138, 439] have noted that an abundance of milk sugar or malt soup or, as Freund expresses it, "anything which promotes the formation of acid" by fermentation or otherwise will reduce the production of insoluble soaps. Anything on the other hand which induces putrefaction or production of alkali increases or at least favors the production of soaps in the stool. Freund's table on the influence of carbohydrate is instructive.

TABLE 68.—INFLUENCE OF CARBOHYDRATE ON THE PRODUCTION OF INSOLUBLE SOAP (FREUND)

Period	Food supplement	Daily fat		Insoluble soaps, per cent. of total fat	Percentage utilization
		Intake, grams	Output, grams		
I	Cereal.	14.39	0.437	46.7	96.7
II	Saccharin water.	15.19	0.422	42.1	97.2
III	Milk sugar.	13.74	0.682	13.8	95.0
IV	Cereal and sesame oil	28.12	1.043	7.9	96.3
V	Cereal and malt soup.	15.23	0.940	5.9	93.8

The greatest reduction occurs with milk sugar and malt soup. Because of the interference with soap formation in the intestine when milk sugar was added the output of fat is greater than in the preceding period and the utilization is lower. It is only in this indirect way that carbohydrate can interfere with utilization of fat. Talbot and Hill[419] in a single infant found that the utilization of total fat was not influenced by the amount of lactose in the diet except when an acid diarrhea was produced. Their findings confirmed the earlier results of Fife and Veeder[119] in this regard.

Freund, L. F. Myer, Bosworth and Bowditch and others have witnessed the increase of soaps under the influence of proteins. Freund states that even a simple addition of buttermilk to the food of a breast-fed child will change the characteristic breast stool of whatever type to a dry, formed or even solid evacuation with a gradually developing odor of putrefaction, in which the bilirubin has been changed to hydrobilirubin and the acid reaction has given way to alkaline. It should be remembered in this connection that evidence was given above (p. 761) against the conception that a dry, hard stool is necessarily very much richer in soap, and in favor of the idea that the main difference is water. Granting, however, that more soaps may be present (Table 62) Freund's explanation seems to be perfectly plausible. He declares there is nothing else present in the buttermilk which can produce the effect and finds that the same changes can be produced by addition of nutrose. The position of Bosworth and Bowditch has already been given (p. 763).

4. *Alimentary Secretions.*—Since the digestion of fat depends so largely upon the pancreatic secretion and its absorption depends so largely upon the presence of bile in the intestine, we should naturally expect any failure of either of these secretions to alter very materially the utilization of fat, as well as the distribution of the fat to its several component fractions. A case reported by Finizio[122] illustrates well the effect of interruption of pancreatic secretion. The case was one of acute pancreatitis following mumps in a child eleven months of age. After receiving for three days a test diet of 480 c.c. of milk, 240 c.c.

water and 10 gm. "Greiss" the child delivered a stool which showed 5 per cent. only of the fat as soap, 11 per cent. as fatty acids and 82 per cent. as neutral fat. Comparing this with the normal percentages seen in Table 59, page 758, it is obvious that the pancreatic function was largely in abeyance.

The case reported by Koplik and Crohn[239] on page 737, illustrates well the effect of suppression of bile upon the absorption of fat. Other cases have been reported by Niemann,[325] and by Parker.[343] In all of these not only was the total fat excretion enormously increased but the distribution of fats was also greatly changed. The three cases may be compared as in the following table:

Table 69.—Effect of Suppression of Bile upon Fat in the Stools

Case of	Age	Fat intake	Distribution of fat as		Utilization of fat
			Fatty acids and soaps	Neutral fat	
Koplik and Crohn....	10 weeks	24.5	22.6	77.4	48.4
Niemann............	9 weeks	36.4	91.0	9.0	39.0
Parker..............	4 years	112.0	63.8	36.2	55.0

Obviously the degree of disturbance to fat absorption and utilization will depend upon the degree of suppression and upon the amount of fat ingested. In Niemann's case the cleavage of fat apparently is not disturbed, although the absorption is interferred with more than in the other cases.

Utilization of Ash Constituents.—In addition to the general technical difficulties attending the determination of mineral constituents in the excreta two special circumstances have served to delay exact information on the absorption of ash constituents in the body. One of these is the occurrence of inorganic constituents as necessary components of the alimentary juices, the excretion of certain of them by the wall of the large intestine and the utter impossibility of separating the portion originating in the food from that which originates in the digestive tract. The situation in this respect is much the same as with the proteins. The other circumstance is that relatively long observational periods are required because the metabolism of inorganic substances proceeds much more slowly than is true of organic snbstances. The field of mineral metabolism has been assiduously cultivated in spite of these difficulties and new knowledge is rapidly accumulating. In this section the only question with which we are concerned is the *utilization* of ash constituents—the amount as well as the influences by which it is varied within normal limits.

Since the milk of the cow differs greatly in the percentage of ash which it contains from mother's milk, we should naturally expect the utilization from the two would be different. The following table from Bosworth and Bowditch[54] gives the composition of the two milks both on the basis of the "ash in 100 c.c." and in 100 c.c. of milk. It is necessary to make this distinction because "the process of incineration leaves an ash in which the arrangement of the elements is altogether different from the original milk." For example, part of the phosphorus is combined with casein, all of the sulphur is combined either with albumin or casein, some of the calcium is in combination with protein, some with phosphate, etc. Upon ashing the organic molecules are destroyed, the mineral elements are converted to oxides, and some of them (notably *S* and *P*) almost inevitably are lost by volatilization. For this reason the higher figures should be used.

Table 70.—Composition of Human Milk and Cow's Milk (Bosworth and Bowditch)

Mineral substance	Human milk		Cow's milk	
	In ash of 100 c.c.	In 100 c.c. milk	In ash of 100 c.c.	In 100 c.c. milk
K_2O	0.086	0.086	0.145	0.145
Na_2O	0.020	0.020	0.074	0.074
CaO	0.050	0.050	0.201	0.201
MgO	0.005	0.005	0.022	0.022
Cl	0.038	0.038	0.076	0.076
SO_3	0.002	0.004	0.025	0.054
P_2O_5	0.034	0.036	0.199	0.249
Total	0.235	0.239	0.742	0.821
Subtract O_2 for Cl	0.008	0.008	0.017	0.017
Net total	0.227	0.231	0.725	0.804

Cow's milk it will be observed contains twice as much chlorine and potassium (nearly), four times as much calcium, magnesium and sodium (nearly), eight times as much phosphorus and more than twelve times as much sulphur as mother's milk. In addition to the quantitative differences are others of a qualitative nature which may be seen in the table from the same authors given on p. 763. Thus cow's milk contains a considerable amount of its phosphorus as di-calcium and di-potassium phosphates; human milk contains none in either of these forms. Such differences as well as those which affect percentages merely have their influence on absorption.

Total Ash.—A number of estimations of the percentage utilization of the total ash have been made in recent years from which the following from Tobler and Noll,[430] and Lindberg[269] on breast-fed, and from Hoobler[207] and Holt, Courtney and Fales,[205] on bottle-fed infants may be selected.

TABLE 71.—UTILIZATION OF TOTAL ASH IN BREAST-FED AND BOTTLE-FED INFANTS

Author	Subject	Mother's milk		Abs.	Per cent. utilization	Remarks
		Intake	In feces			
Tobler and Noll	2½ months	1.142	0.399	0.743	65	
Lindberg	I 2½ months	1.479	0.529	0.950	64	
	II 2½ months	1.471	0.582	0.889	60	
		Cow's milk				
Holt, Courtney and Fales	Average of 7 children, 4 months to 10 months				60.0	
Hoobler	I 9 months	8.969	4.265	4.704	53.0	2.1 per cent. fat in food
	II 9 months	9.481	3.139	6.342	66.8	4.0 per cent. fat in food

It is remarkable that the utilization in the two groups should be so nearly the same. The result is quite out of harmony with older observations—for example: those of Wegscheider,[459] Uffelmann,[435] Blauberg[43] and Heubner.[193] According to Biedert[38] who worked over the analyses of Blauberg and compared them with average analyses of the two milks, the utilization of total ash in breast-fed infants is about 77 per cent. and that of infants fed on cow's milk only 65.1 per cent. Biedert's table is presented because of the interesting differences which he found in the distribution of ash constituents between the stools of two infants analyzed by Blauberg as well as between the two milks upon which they were fed.

TABLE 72.—DISTRIBUTION OF CONSTITUENTS OF SOLUBLE ASH IN STOOLS FROM MOTHER'S MILK AND COW'S MILK, AS WELL AS IN THE TWO MILKS THEMSELVES (BIEDERT, FROM SCHMIDT AND STRASBERGER)

	Feces from mother's milk	Mother's milk	Feces from cow's milk	Cow's milk
Per cent. content of dry substance in ash	14.3	.....	16.41	
Per cent. content of ash constituents soluble in HCl	52.6	.....	69.01	
Per cent. content of soluble ash in—K_2O	15.0	31.36	11.27	22.01
Na_2O	4.2	6.77	.....	6.99
CaO	31.15	16.59	34.69	21.88
MgO	8.75	2.74	5.33	2.81
Fe_2O_3	1.91	0.20	1.50	0.33(!)
Cl_2	3.45	18.86	3.40	15.47
SO_3	3.81	2.45	2.62	0.58
P_2O_5	11.81	22.65	15.28	27.01

It is evident from this table that the percentage of calcium, magnesium, iron and of sulphate is higher in the soluble ash of the stool than in the milk which occasioned the stool; but that the reverse is true of the alkaline bases and the chlorides and phosphates. The differences are accounted for by the fact that all four elements of the former group are excreted chiefly through the stool, while all four of the latter are excreted mainly through the urine. The table shows also that with the exception of calcium and phosphorus there is a slightly greater amount (relative to total soluble ash) of all the elements in the stools of breast-fed infants. The utilization of ash by infants of different ages has not been studied by modern methods, so that the lower percentages given in Table 71 for breast-fed infants as compared with the older results of Blauberg and others may be due in some measure to an age difference. It is more probable that the methods of analysis in vogue twenty-five years ago were at fault. It may be noted in passing that the ash content of milk varies with the period of lactation (page 616) and that this applies to cow's milk[434] as well as to mother's milk. The tables above must be accepted as representing average conditions as regards the composition of milks and, with the exception of Holt's results, as individual instances regarding the composition of stools.

Calcium.—If one mineral could be regarded as more important than any other whether in the normal or pathological metabolism of infants that element, to judge by the attention devoted to it in the past twenty-five years, would be calcium. Perhaps it is because the need of calcium for growth of the skeleton is so obvious and also because it has been regarded as representing one of the outstanding differences between mother's milk and cow's milk that so much attention has been centered upon this element. Its ready disposition to unite with fatty acids in the formation of insoluble soaps has made its presence in the stools conspicuous and the significance of the losses thereby incurred has been one of the storm centers of discussion. Another has been the question of form in which it is best administered especially in the treatment of rickets. This question is one of retention rather than utilization and need be considered here only as it affects utilization.

A relatively small part (5 to 10 per cent.) only of the calcium intake normally appears in the urine, all the rest (not retained) being eliminated in the feces. Hence it would seem at first glance that the problem of retention (growth) is mainly one of absorption. Anything which favors absorption should favor growth. We must remind ourselves, however, that calcium is one of the few elements which is known to be excreted from the blood through the walls of the colon, the calcium percentage of dry weight in the contents of the large intestine, being actually higher than in the contents of the small intestine. Hence absorption in the upper bowel may be good, but if the calcium cannot be converted to use in growth of bone it may find its way out, possibly in the same experimental period, through the walls of the lower bowel. This but emphasizes the fact that the real seat of calcium hunger as of oxygen hunger in energy metabolism (page 522) is in the tissues themselves. Filling the intestine with calcium or making it more soluble has no more effect upon growth than filling the lungs with oxygen has upon the general processes of oxidation. The stimulus to retention and growth must come from within. Much debate over the matter of insoluble soap might have been spared if these principles had been kept clearly in view. Incidentally, the property of vitamines to promote both utilization and retention not only of mineral elements but also of proteins doubtless will find its basic explanation in events beyond the alimentary tract.

Following the discovery by Keller[224] and Steinitz[414] that an increase of ammonia in the urine may be caused by loss of alkali through the feces came the observations of Rothberg[377] and of L. F. Meyer[303] that much calcium may be lost by the stools when a high-fat milk is ingested. The anxiety to find an explanation of disturbances which follow high-fat feeding doubtless led to an exaggeration of the amount of such losses, and more careful comparison of the calcium content of normal stools would have shown that the difference is really not so great after liberal feeding of fat. At all events this has now been established by the observations of Wolff,[468] Niemann,[326] Hoobler,[207] Holt, Courtney and Fales,[205a] for normal infants and by Fife and Veeder[119] for atrophics. Hoobler indeed claims that the utilization of calium in his one case was better on 5.4 per cent. fat than upon 2.1 per cent. Wolff's and Niemann's experiments also were made each upon a single infant. The former gave first a meager diet upon which the child lost weight and later a full diet of whole milk. He could see no harmful effect of fat upon the calcium utilization. The latter kept the calcium intake constant while passing from a low (1.1 per cent.) fat to a high (4.0 per cent.) fat diet and likewise was unable to find any difference in utilization or retention of calcium. Holt's work was more extensive. Thirty healthy infants all bottle fed, ranging from two to sixteen months of age were selected. The calcium intake and stool collections were exactly known; the calcium in the stools was determined by McCrudden's[290] method. Grouping the cases according to the character of the stools the following comparison was made.

TABLE 73.—RELATION OF AVERAGE CALCIUM EXCRETION TO AVERAGE SOAP EXCRETION (HOLT, COURTNEY AND FALES)

Stools	Number of cases	CaO intake, grams daily	CaO in stools, grams daily	Fat as soap in stools, grams daily	CaO possibly held as soap	CaO not held as soap	CaO possibly soap, percentage of	
							CaO in stools	CaO intake
Constipated.........	7	1.22	0.82	2.35	0.24	0.58	30.9	19.5
Normal.............	9	1.45	0.92	2.04	0.20	0.72	22.6	14.4
Soft normal.........	7	0.97	0.59	1.31	0.13	0.46	20.4	14.4
Non-homogeneous...	7	1.11	0.64	0.90	0.09	0.59	20.3	10.1

The last two columns of this table give the percentage of calcium in the food and in the stools which could have been eliminated as calcium soaps. The amount excreted in this form was never as much as half and seldom more than three-tenths of the calcium in the stools. It never rose to this proportion of the calcium intake. Constipated stools show a higher excretion as soaps notwithstanding a lower intake of fat than in the cases with normal stools. The column headed "CaO not held as soap" gives the maximum values for calcium put out as phosphate. This fraction of the calcium also is influenced more by the intake than by the amount of fat excreted.

The best utilization of calcium, it was found, occurred when the calcium intake bore a definite relation to the fat intake (0.045 to 0.060 gm. CaO to each gram of fat) and when the total fat ingestion was fairly high (not less than 4.0 gm. per kilogram). With older children[205a] one to five years taking mixed diet, *i.e.*, milk with other foods, there was again no close relation between calcium excretion and fat intake or fat excretion. The calcium lost as soap was in most cases an insignificant part of the calcium intake, but the absorption of calcium was not good unless the calcium intake bore a suitable ratio to the fat intake.

The following table gives the utilization of calcium by infants on mother's milk and cow's milk, calculated from a table after Orgler given by Czerny and Keller[86] to which are added the results obtained by Hoobler.

TABLE 74.—UTILIZATION OF CALCIUM BY INFANTS ON MOTHER'S MILK AND COW'S MILK (ORGLER)

Author	Age of child, months	Food	Daily intake of CaO	Daily output of CaO in feces	Per cent. utilization
		Breast Milk			
Schlossmann	1	Breast milk	0.332	0.133	60
Schlossmann	1¾	Breast milk	0.423	0.242	43
Peiser	1¾	Breast milk	0.279	0.211	24
Tobler and Noll	2½	Breast milk	0.239	0.148	38
Michel and Peret	2½	Breast milk	0.377	0.198	48
Schabad	3¾	Breast milk	0.364	0.163	55
Blauberg	5	Breast milk	0.272	0.066	76
		Cow's milk			
Orgler	2⅓	½ milk and ½ cereal soup, sugar	0.702	0.559	15
Peiser	2½	Eiweissmilch	0.728	0.591	19
Cronheim and Müller	4	¾ milk and milk sugar	1.351	0.923	32
Arndt	5½	Maltsoup	0.611	0.185	69
Cronheim and Müller	6	¾ milk and milk sugar	1.273	1.094	14
Freund	8	½ milk, ½ cereal soup and malt	0.754	0.538	29
Niemann	10	II period, 1 liter skim milk	1.638	1.285	21
		III period, 1 liter fat, whole milk	1.798	1.051	42
Hoobler	9	II period, 4.0 per cent. fat	2.050	1.696	17
		III period, 5.4 per cent. fat	2.092	0.951	55

The last two cases illustrate in a striking way the fact that the utilization of calcium from cow's milk is not diminished by high fat in the food. No attempt was made by any of these observers to analyze the factors which determine the losses through the feces, or to separate unabsorbed calcium from calcium excreted through the intestinal wall.

This has been done by Orgler[335] who reached the conclusion that the effect of milk fat is not to be referred primarily to its action upon the alimentary processes but to changes in the intermediary metabolism whereby the conditions for storage of fat are affected unfavorably, the result being an increased elimination of calcium. The much lower percentage utilization on cow's milk which is evident in Table 74 is certainly not to be ascribed to the formation of insoluble soaps but to the very large amount of calcium contained in cow's milk, much of it already in insoluble form (p. 763). The calcium of dried milk may be in more suitable form for absorption; for Givens and Mendel[153] have found that 0.34 gm. CaO in this form was sufficient to maintain a dog in positive calcium, whereas 1 gm. of CaO in the form of calcium lactate was necessary to accomplish the same end. That the reaction of the stool may not be without significance in this matter of utilization is to be inferred from the demonstration of Blühdorn[47] that a precipitate of calcium phosphate from a solution of alkaline sodium phosphate and calcium chloride may be thrown down by the extract of an alkaline or neutral stool but not by the extract of a strongly acid stool. Addition of acid and base to the food, however, were without effect upon utilization in the experiments of Mendel and Givens.

So far as the writer can find only one experiment has been made on the utilization of calcium in a breast-fed infant where special attention was given to the influence of fat. Lindberg[269] studied the mineral metabolism of a two-and-one-half-months healthy infant while on a six-day period of mixed breast milk of known composition and then raised the fat by addition of fat of breast milk to 5.6 and 5.7 per cent. for a further period of six days. There was no increase in the formation of soap found in the stools, but there was more calcium in the stool so that the *retention* of calcium as well as its apparent utilization was affected unfavorably. Indeed in the second half of the fat-period there was a net loss of 0.033 gm. CaO daily. The author in his conclusions agrees with the position taken by Orgler, namely, that the unfavorable influence of fat upon the utilization of calcium by the infant must be referred to the intermediary metabolism.

Support for this view may be seen also in the experiments of Kochmann[233] and of Kochmann and Petsch[235] on dogs. Feeding a calcium-poor diet of dog cakes or of horse flesh these observers noted a distinct dependence of the calcium metabolism upon the nitrogen metabolism. Calcium in the feces rose whenever the fecal nitrogen rose, and to maintain a calcium balance it was necessary to feed calcium in sufficient quantity so that the relation of CaO : N in the food was 1:3 or greater. On a diet of horse flesh the loss of P_2O_5 was larger than corresponded to the N alone and was equivalent to the loss of CaO in addition when that element was calculated as the tri-calcium phosphate. The elimination of calcium took place almost exclusively through the feces. The authors conclude that the calcium loss comes from the skeletal system in the form of phosphate and serves in some way in the intermediary metabolism as a detoxicating material. These results in turn recall those of L. F. Meyer[301] who found that adding protein to an insufficient diet for maintenance of weight in infants caused a poorer utilization of calcium, although the retention of total ash was improved.

For a brief discussion of the influence of the antagonistic action of magnesium on calcium utilization, see below.

Magnesium.—The utilization of magnesium so far as it has been determined in infancy is not so regular as is that of calcium. This may be due in part to the smaller quantities present and the consequent greater error in the analysis. The more recent and apparently more trustworthy results reveal a lower percentage utilization than did the older studies. Relatively more magnesium than calcium appears in the urine. The well-known antagonism between magnesium and calcium appears to play a part in the utilization as well as in the retention of both elements. This is well illustrated in the following experiment by Malcolm[280] on the dog. Following a normal period calcium chloride was added to the diet and after another normal period magnesium chloride was added. The calcium had but little effect on the excretion of magnesium by urine or feces but the magnesium produced a considerable increase in the excretion of calcium by both routes. This

TABLE 75.—UTILIZATION OF MAGNESIUM IN INFANCY

Author	Age, months	MgO intake	MgO in stool	Per cent. utilization	Remarks
			Breast-fed		
Blauberg	5	0.047	0.016	73	
Lindberg	2½ I	0.051	0.015	70	
	... II	0.048	0.024	51	
			Bottle-fed		
Hoobler	9 II	0.078	0.030	61	4.0 per cent. fat
	...III	0.150	0.083	45	5.4 per cent. fat
Holt, Courtney and Fales	Average of 7 normal infants, 2 to 10 months			43	

TABLE 76.—INFLUENCE OF MAGNESIUM ON CALCIUM EXCRETION (MALCOLM)
Subject—Dog of 7.7 kg.

	Fed		Urine		Feces		Total		Balance	
	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg
I. Normal	0.394	0.150	0.019	0.038	0.444	0.100	0.463	0.138	−0.069	+0.012
II. $CaCl_2$	0.588	0.150	0.016	0.048	0.555	0.098	0.571	0.146	+0.017	+0.004
III. Normal	0.394	0.150	(0.016)	0.035	0.442	0.096	0.458	0.131	−0.069	+0.019
IV. $MgCl_2$	0.394	0.319	0.043	0.075	0.484	0.221	0.527	0.296	−0.133	+0.023

effect of magnesium to increase calcium excretion was seen by Jacoby[215] also in the human subject after the administration of magnesium sulphate in the treatment of tetanus. The observation is perhaps significant in view of the use of magnesium in the treatment of spasmophilia[36] and of tetanus neonatorum.

The behavior of magnesium to high fat feeding may be quite independent of that of calcium. Birk[40] observed that its utilization is diminished when fat is high in the food and his observations have been confirmed by Hoobler.[207] A harmful effect of carbohydrate in young infants was also seen by Birk but it was absent in the case of a 10-months child. Holt and his colleagues[205] noted that in diarrheal stools the entire magnesium content of the food may be lost in the stool, from which they infer that magnesium is slow to enter into combinations which favor its absorption. The same observers[198] studying the elimination of magnesium sulphate injected subcutaneously in infants found no increase in the stools. Magnesium, therefore, unlike calcium does not appear to be excreted from the blood by the colon.

Phosphorus.—Because the utilization of phosphorus is so closely related to that of calcium and magnesium it may be considered in this place. A rather large percentage of the phosphorus found in the "normal" feces has its origin in the intestinal secretions. This is proved by the experiments of Lipschütz[270] on the dog in which the percentage of dry substance in the feces as phosphorus remained nearly constant at 0.6 per cent. notwithstanding large variations of total P in the food. Blauberg[44] found the corresponding percentage in the stools of a healthy breast-fed infant to be 0.26 to 0.49 with an average of 0.34 per cent.

The principles governing utilization of phosphorus may be illustrated by the following experiments of Oeri[330] on adults. When the food was of animal origin (rich in P and poor in Ca) the distribution of phosphorus to the urine and feces could be altered at once by giving calcium carbonate. Combining with the P_2O_5 as insoluble phosphate the calcium carried the phosphorus out by way of the feces. Milk added to the diet had the same effect. When sufficient calcium was present for the purpose the P_2O_5 of the feces could be increased by giving this element in the form of inorganic phosphates or organic compounds like lecithin and nucleic acid, containing phosphorus; for as soon as the phosphorus was set free from organic combination by digestion it behaved in the same manner as inorganic phosphate.

In nutrition of the infant the loss of phosphorus by the intestine will depend upon the kind of milk fed. By reference to Table 64 on page 763 it may be seen how much cow's milk differs from human milk as regards the salts present. In human milk there are no insoluble phosphates but only the soluble mono-magnesium and mono-potassium phosphate. In cow's milk abouts two-thirds of the total phosphates are in soluble forms and one-third in the form of the insoluble di-calcium phosphate. In goat's milk[52] in addition to di-calcium there are also tri-calcium, di- and tri-magnesium phosphates all of which are insoluble, while the soluble phosphate is the mono-potassium phosphate alone. The soluble phosphates in so far as they are not retained for growth, and the insoluble phosphates in so far as they may be broken up by the acidity of the gastric juice, are eliminated in the urine of the child.

With high-fat in the milk some of the calcium set free from inorganic or organic combination which would otherwise be eliminated in combination with phosphorus combines with fatty acids and is eliminated as insoluble soap leaving relatively more phosphorus to be eliminated through the urine. For example: Freund[136] in two experiments on infants whose food was increased by the addition of butter fat or of cream obtained from breast milk observed an increased utilization of phosphoric acid from 37.6 to 46.5 per cent. in one case and from 46.0 to 55.6 per cent. in the other. Hoobler's[207] case in three different periods with 2.1, 4.0 and 5.4 per cent. fat respectively showed a utilization of 67, 78 and 83 per cent. in the corresponding periods. Feeding cod liver oil improves the utilization[417] quite independently of the salts of the food, probably through the stimulus of its fat-soluble vitamine on the growth of bone and other tissues.

In feeding fats combined with phosphorus (lecithin) to infants 4 to 11 months (also one child two and one-half years) Cronheim and Müller[84] were unable to make out any difference in net utilization but found a slight increase in the organic phosphorus of the feces. Following Eiweissmilch Peiser[347] found more phosphorus in the stool than was present in the food itself in proportion to the nitrogen. The comparative utilization of P_2O_5 in breast-fed and bottle-fed infants may be seen in the following table compiled from authors already cited.

Table 77.—Utilization of Phosphorus in Infants on Breast Milk and Cow's Milk

Author	Age, months	P_2O_5 intake	P_2O_5 in stools	Per cent., utilization
			Breast milk	
Tobler and Noll...	2½	0.210	0.034	84.0
Lindberg........	2½–I	0.294	0.055	75.0
	II	0.289	0.062	79.0
Blauberg........	5	0.203	0.022	89.0
			Cow's milk	
Keller...........	2¾	0.825	0.107	87.0
Hoobler.........	9	2.215	0.765	67.0
Holt............	Average of 7 normal infants, 2 to 10 months of age			63.1

In older children the utilization of phosphorus is determined by the factors which have already been discussed. When mixed diet is taken, especially one rich in cereals and vegetables containing calcium, the phosphorus is more largely excreted through the feces than upon a diet richer in meats. Herbst[182] in his very interesting studies on boys 6 to 14 years of age, eating a liberal diet chosen according to taste, found that about one-half of the phosphoric acid ingested was eliminated through the urine and approximately one-fifth through the feces. The food contained from 3 to 4 gm. P_2O_5 daily.

Iron.—Two important reviews of the metabolism of iron were published in the years 1906 and 1907—one by Abderhalden,[2] the other by Meinertz.[294] The first-named author, speaking with reference to the absorption of iron as made out by the ammonium sulphide method after feeding milk to which iron salts had been added, states that, "there is obtained little if any reaction for iron in the stomach, while in the duodenum there is a marked green coloration. If the tissue of the intestine is examined under the microscope numerous little kernels containing iron are to be found embedded in the protoplasm of the intestinal epithelium, and for the most part these are directly beneath the cuticular borders of the cells. Now and then tiny leucocytes may be seen laden with innumerable little particles of iron. These are noticed in the stroma of the villi. In the submucosa also cells containing iron may be noticed once in a while. In the jejunum, however, it is quite different. Here, as a rule, the iron reaction is shown only in the solitary follicles and in the Peyer's patches. In the ilium, the iron reaction is not, as a rule, very pronounced while the cecum and large intestine again give a strong test. Coming from the intestinal canal, especially the duodenum, lymphatics filled with cells containing iron may often be seen leading to the mesenteric glands, which likewise show a pronounced iron reaction. The liver and spleen now give a very strong test and evidently these organs serve as storage places for iron salts."

These results were obtained[59] with mice, rats, rabbits, guinea pigs, dogs and cats, after giving from 0.4 to 0.5 mg. of iron daily to the rats and 3 to 5 mg. daily to dogs and cats. It was found by Abderhalden[1] "that animals fed exclusively upon meat or exclusively upon vegetables gave exactly the same reactions for iron in the intestine and in the tissues as those which were dosed with iron salts." Abderhalden believed, therefore, that it was proved satisfactorily that organic and inorganic iron are absorbed by the same routes, but from various considerations, which need not be entered into here, he thought it was not yet demonstrated that hemoglobin can be formed from its organic precursor (hematoporphyrin) and inorganic iron.

Meinertz differed from Abderhalden in believing that iron is absorbed mainly in organic combination, and that even inorganic iron does take part in the production of hemoglobin. He states further that the intestines and especially the large intestine takes part in the elimination of iron. To a lesser extent the liver, through the bile, and the kidney participate in the process. Iron fed in excess likewise is eliminated, after having been stored temporarily in the liver and elsewhere, for the most part through the intestine. The kidney scarcely participates in this and the liver not at all. On the other hand, iron derived from the destruction of hemoglobin and probably also from the tissue cells (for all tissues contain iron) is eliminated for the most part through the urine.

Important contributions concerning the absorption and utilization of iron added since these reviews are the following: Iron fed in albuminate form (ferratin) is absorbed, and increases the albuminate store of iron in the liver.[51] Fed in this form it is absorbed probably as an iron alkaline peptone.[386] Kochmann[234] found that the quantity of iron absorbed depends upon the kind of organic food fed with it. If carbohydrate or fat is fed with a measured amount of iron which itself gives a positive balance a negative balance may result. Or, on the other hand, the addition of such foods to a regimen containing ferratin, metaferrine or phosphate of iron, which itself produces a negative balance, may bring about a positive balance and retention of iron. Finally, ingestion of foods which are equally favorable for the metabolism of iron does not have the same value for the metabolism of nitrogen. Inorganic iron does not modify the nitrogenous metabolism while organic iron influences it favorably, *i.e.*, favors retention. Korsunsky[242] demonstrated that the absorption of iron in rabbits with biliary fistulæ was not as great after feeding 0.06 per cent. of the perchloride as in normal rabbits, from which he inferred that the bile aids in the absorption even of inorganic iron. Leone[262] gave dogs with biliary fistulæ organic iron and found that the iron of the bile was augmented much more when it was given by mouth than when it was injected subcutaneously. Inorganic iron did not increase the elimination through the liver. Studying the influence of iron salts on the formation of kynurenic acid from tryptophan Homer[206] made the observation that the feces of the dog after administration of iron salts were not black as usual because the tryptophan which ordinarily yields indol compounds was more completely changed into kynurenic acid and was eliminated in this form through the urine.

Coming now to the utilization of iron in infants we have the important observations of Krasnogorsky[243] who studied the subject after feeding with both mother's milk and goat's milk and both raw and heated milk. His results show that the iron compounds of mother's milk are incomparably better absorbed and retained than are those of goat's milk. The absorption was also much better from heated milk than from raw milk.

According to McLean[293] the iron of goat's milk amounts to 2.02 to 4.2 mg. of Fe_2O_3 per liter, while according to Bahrdt and Edelstein[27] the iron of milk from three wet nurses was 1.63, 1.76 and 1.93 mg. Fe_2O_3 per liter. The lower percentage in mother's milk Krasnogorsky observed was more than compensated by the better utilization. The iron of spinach and egg yolk were equally utilized in older infants but both fell far behind that of breast milk. The natural compounds also are more abundantly absorbed and probably in more favorable form than the iron of artificial preparations. Since the functional sphere of iron is not limited to the formation of hemoglobin but is essential to the process of oxidation in all the tissues (p. 553) insufficient feeding of iron may have far-reaching consequences.

The only available data on the utilization of iron in infants are the following from Krasnogorsky and from Langstein and Edelstein.[257]

TABLE 78.—UTILIZATION OF IRON IN INFANTS

Author	Age of infant	Food	Fe intake, milligrams	Fe in feces, milligrams	Per cent. utilization
Krasnogorsky..........	..	Mother's milk	7.1	0.84	88.1
		Goat's	3.4	2.59	24.7
Langstein and Edelstein.	12 Mo.	Expressed M.M.	7.79	4.11	47.0
	8 Mo.	Expressed M.M.	7.01	4.56	35.0
	Newborn	Expressed M.M.	III.–0.736	0.942	.... 1st 5 days
			IV.–1.432	0.826	42.0 2d 5 days

The iron content of cow's milk according to Nottbohm and Dörr[329] lies between 0.3 and 1.3 mg. Fe_2O_3 per liter, the higher figures being obtained from milk drawn near the end of lactation. But Edelstein and Csonka[107] found that when milk was drawn directly into glass the values were only 0.6 to 1.0 mg. Fe_2O_3 with an average of 0.7 mg. per liter. Higher values they ascribe to the practice of handling milk in vessels containing iron. Cow's milk, therefore, contains from one-third to one-half less iron than mother's milk. These results are in agreement with those of Soxhlet[410] who points out that in the ordinary dilutions of cow's milk one is dealing with a food which affords only one-sixth to one-tenth the iron of breast milk. It has been known since the early observations of Quincke (1868) that iron is eliminated from the blood through the wall of the intestine and this has since been abundantly confirmed by Hamburger,[171] Fritz Voit,[454] Lapicque[260] and others. Hence the necessity, as in the metabolism of other heavy metals, of making a clear distinction between utilization and absorption.

Other Mineral Elements.—Because of the paucity of information regarding the utilization of the remaining mineral elements in infancy they will be grouped together in this section. The elements most commonly considered in mineral metabolism are, in addition to those previously discussed, sodium, potassium, chlorine and sulphur. All of those in contrast with calcium, magnesium, phosphorus and iron are eliminated chiefly in the urine. It is probably because they are so readily absorbed that little attention has been paid to their utilization in infancy.

In Table 79 are brought together the few scattered data available for normal infants. For the most part these are derived from sources already mentioned and constitute the latest information extant. The agreement as between different authors is fairly satisfactory, and the agreement between infants fed on mother's milk and others on cow's milk as regards percentage utilization is surprisingly close. The only discrepancy of consequence is in the sulphur.

TABLE 79.—UTILIZATION OF SODIUM, POTASSIUM, CHLORINE AND SULPHUR

Author	Age of infant	Sodium			Potassium			Chlorine			Sulphur		
		In food	In feces	Per cent. utilization	In food	In feces	Per cent. utilization	In food	In feces	Per cent. utilization	In food	In feces	Per cent. utilization
(Mother's milk)													
Tobler and Noll. .	2½	0.221	0.0085	61	0.343	0.058	83	0.069[1]	0.003	91	0.137[3]	0.036	74
Lindberg.	2½–I	0.131	0.032	75	0.432	0.082	81	0.419[2]	0.021	95			
	. . .–II	0.162	0.046	72	0.442	0.108	76	0.421[2]	0.040	93			
Blauberg.	5	0.588	0.192	67	. . . . .	. . . . .	. .	0.330[2]	0.013	96	0.0396[4]	0.0096	76
Klotz.	?	. . . . .	. . . . .	. .	1.103	0.284	74						
(Cow's milk)													
Blauberg.	7	. . . . .	. . . . .	. .	1.57	0.271	83	. . . . .	. . . . .	. .	0.583[4]	0.148	75
Soldner.	?	0.409	0.098	74									
Hoobler	9–I	2.1% fat	. . . . .	. .	. . . . .	. . . . .	. .	2.318	0.042	99	0.463[4]	0.054	88
	. .–II	5.4% fat	. . . . .	. .	. . . . .	. . . . .	. .	2.343	0.060	97	0.444[4]	0.019	96
Holt.	Average of 7, 2–10 months			88	. . . . .	. . . . .	85	. . . . .	. . . . .	96			

The only factor known to be of importance in affecting the amount of alkalies eliminated through the feces is the amount of fat in the food. We have already been obliged to discount the prophesies of serious consequence from loss of calcium under the influence of fat and it is probable the consequences to sodium and potassium absorption from this cause alone have been over emphasized. Steinitz[414] published results of three experiments in which the sodium, potassium and calcium were determined in both urine and feces during a period of skim milk feeding and a subsequent period with cream added. The results of one of these experiments are given in Table 80.

Table 80.—Effect of Fat on Elimination of Sodium and Potassium (Steinitz)

		Urine		KCl				NaCl			
	N	$NH_3 - N$		Intake, grams	In feces, grams	In urine, grams	Per cent., utilization	Intake, grams	Feces, grams	Urine, grams	Per cent., utilization
		Milligrams	Per cent.								
Skim milk....	1085	51.8	4.9	0.755	0.182	0.578	75.9	0.378	0.084	0.566	77.9
Cream.......	829	119.7	14.5	0.658	0.434	0.243	34.0	0.350	0.367	0.132	0.0

The alkalies, it is likely, are diverted not so much because of their combination with fatty acids as soluble soaps (for this always occurs normally) as because of excessive peristalsis and want of time to be absorbed. At all events this is just what happens to the soluble alkalies in diarrheal stools.[197] L. F. Meyer[301] observed unfavorable effects of the same character upon sodium absorption after feeding proteins (casein) and fat to infants which had been brought into a low state of nutrition; but after fat alone the only elements which suffered in the percentage utilization were calcium and phosphorus.

Reaction of the Stools in Infancy.—This topic has long been one of some interest to pediatrists. Stools from cow's milk, in normal infants, in contrast with those from breast milk are alkaline. The acid reaction of breast-milk stools is due to the volatile acids which according to Bahrdt and McLean[28] may require 22 c.c. N/10·NaOH to neutralize the free acids and 111 c.c. of N/10 NaOH to neutralize the combined acids in 100 gm. fresh stool. Binda[39] likewise finds the free acid in breast-milk stools equivalent to 18 or 19 c.c. N/10 NaOH per 100 gm. fresh stool and asserts that a value as high as 28 to 30 c.c. indicates alimentary disturbance. Cow's milk stools according to this author are also acid, requiring 5 to 10 c.c. N/10 NaOH per 100 gm. The true reaction obviously can only be obtained in terms of the hydrogen ion concentration (p. 714). Recent determinations by Eitel[112] using the gas-chain method, show that in the majority of cases after mother's milk the p_H in normal stools lies between 4.0 and 6.0. In fasting and in constipation on account of the ammonia formed it may be near the neutral point (7.0); while in very loose stools it goes strongly to the acid side. After cow's milk Eitel found values for p_H

between 7.8 and 8.2, acid values being found only in very unusual kinds of stools or alimentary disturbances. When malt soup was given the p_H was well below the neutral point. Eitel believes it is the water soluble salts which determine the reaction in stools of artificially fed infants. There are no free fatty acids in such stools. Since also there are no volatile fatty acids in perfectly fresh human milk it follows that the acids are set free by digestion and by a process exactly comparable with ordinary spoilage while the milk is passing through the alimentary tract. In cow's milk the fat is composed more largely of higher fatty acids and the amount of alkali present is so great as to combine at once any acids set free. Besides there is greater putrefaction and formation of ammonia, on account of richer protein. Weill and Dufourt[460] have found the reaction of stools of artificially fed infants so variable as to be of little clinical significance.

METABOLISM BEYOND THE INTESTINAL WALL

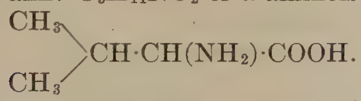
Proteins.—The proteins are without doubt the most important single group of substances entering into the composition of the living body. Upon their physico-chemical properties depend the peculiar reactions of all the vital organs and perhaps of the mind itself. A brief consideration of their chemical nature must be given here.

Exact knowledge of this subject dawned coincidentally with the present century in the discoveries of Kossel and Emil Fischer. The first named gave a method of separating the diamino-acids and the latter investigator a new method of separating and estimating the monamino acids. Many of the individual amino-acids had long been known to occur as cleavage products; but the concepton due to these investigators more than to any others that proteins consist exclusively of such bodies strung together in chains was new and has opened up a world of ideas regarding the function and significance of chemical structure in relation to the living substance.

The list of amino-acids cannot be too familiar and is here reproduced.

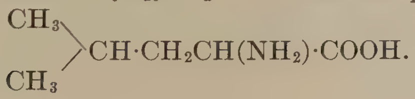
A. MONOAMINO-MONOCARBOXYLIC ACIDS

1. Glycin: $C_2H_5NO_2$, or amino-acetic acid:
   $CH_2{\cdot}NH_2{\cdot}COOH$
2. Alanin: $C_3H_7NO_2$, or α-aminopropionic acid:
   $CH_3{\cdot}CH\ (NH_2){\cdot}COOH.$
3. Valin: $C_5H_{11}NO_2$ or α-aminoisovalerianic acid:



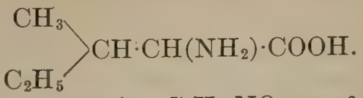
$$\left.\begin{matrix}CH_3\\ \\ CH_3\end{matrix}\right\rangle CH{\cdot}CH(NH_2){\cdot}COOH.$$

4. Leucin: $C_6H_{13}NO_2$ or α-aminoisocaproic acid:



$$\left.\begin{matrix}CH_3\\ \\ CH_3\end{matrix}\right\rangle CH{\cdot}CH_2CH(NH_2){\cdot}COOH.$$

5. Isoleucin: $C_6H_{13}NO_2$, or α-amino-β-methyl-β-ethylpropionic acid:



$$\begin{matrix} CH_3 \\ C_2H_5 \end{matrix} \rangle CH\cdot CH(NH_2)\cdot COOH.$$

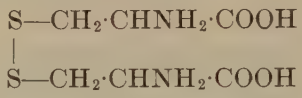
6. Phenylalanin: $C_9H_{11}NO_2$ or β-phenyl-α-aminopropionc acid: $C_6H_5\cdot CH_2\cdot CH(NH_2)\cdot COOH.$

7. Tyrosin: $C_9H_{11}NO_3$ or β-parahydroxyphenyl-α-aminopropionic acid:

$HO\cdot C_6H_4\cdot CH_2\cdot CH(NH_2)COOH.$

8. Serin: $C_3H_7NO_3$, or β-hydroxy-α-aminopropionic acid: $CH_2(OH)\cdot CH(NH_2)COOH.$

9. Cystin: $C_6H_{12}N_2O_4S_2$ or dicystein, or di-(β-thio-α-aminopropionic acid):



$$\begin{matrix} S\text{—}CH_2\cdot CHNH_2\cdot COOH \\ | \\ S\text{—}CH_2\cdot CHNH_2\cdot COOH \end{matrix}$$

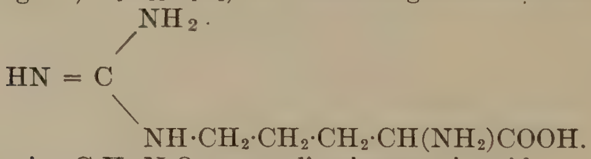
B. Monoamino-dicarboxylic Acids

10. Aspartic Acid, $C_4H_7NO_4$, or aminosuccinic acid. $HOOC\cdot CH_2CH(NH_2)\cdot COOH.$

11. Glutamic acid, $C_5H_9NO_4$, or α-aminoglutaric acid: $HOOC\cdot CH_2\cdot CH_2\cdot CH(NH_2)COOH.$

C. Diamino-monocarboxylic Acids

12. Arginin, $C_6H_{14}N_4O_2$, or α-amino-δ-guanidinvalerianic acid:



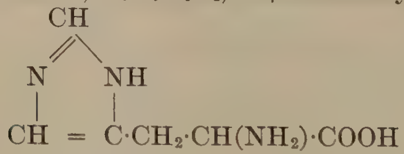
13. Lysin: $C_6H_{14}N_2O_2$ or α-ε-diaminocaproic acid: $H_2N\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH(NH_2)COOH.$

D. Diamino-oxy-monocarboxylic Acids

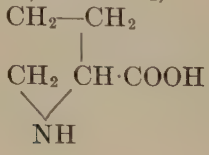
14. Caseinic acid, or diaminotrioxydodecanic acid: $C_{12}H_{26}N_2O_5$.

E. Heterocyclic Compounds

15. Histidin, $C_6H_9N_3O_2$, or β-imidazolyl-α-aminopropionic acid:

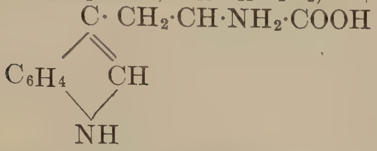


16. Prolin, $C_5H_9NO_2$, or α-pyrrolidin carboxylic acid:



17. Oxyprolin, or oxypyrrolidin carboxylic acid:
$C_5H_9NO_3$

18. Tryptophane, $C_{11}H_{12}N_2O_2$, or β-indole-α-aminopropionic acid:

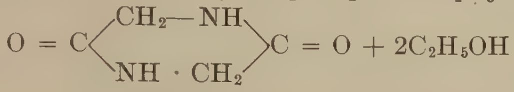


Fischer has shown that the key structure of the proteins is a linkage between the carbon of the carboxyl group in one acid and the nitrogen of the amidogen group in the other. Thus two amino-acids may be concentrated into one molecule by first producing an ester.

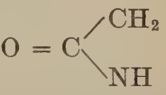
$$\underset{\text{Glycocoll}}{NH_2{\cdot}CH_2{\cdot}COOH} + \underset{\text{Alcohol}}{C_2H_5OH} = \underset{\text{Ethyl-gycocollate}}{NH_2{\cdot}CH_2{\cdot}COO\ C_2H_5} + H_2O$$

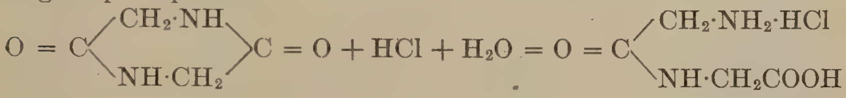
In the presence of water the ester becomes an anhydride thus:

$$NH_2{\cdot}CH_2{\cdot}COOH\ C_2H_5 + NH_2{\cdot}CH_2{\cdot}COO\ C_2H_5 =$$



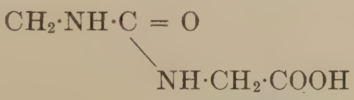
Glycocoll anhydride

The essential linkage is already present; namely, the  grouping. By treatment with an acid like HCl, one end of the closed ring is open up thus:



Glycyl-glycin chlorid

and on treatment with silver oxide the chloride is precipitated leaving glycyl-glycin thus:



Glycyl-glycin

As many as 18 individual molecules (not all different) have been strung together in this way (p. 576) making a molecule the size of an ordinary peptone. The combinations possible are almost infinite in number just as are the possibilities of producing words from letters of the alphabet. Naturally some proteins are much more formidable in their structure than others. Some contain practically all the known building stones, while others are composed of a smaller number. The structure, *i.e.*, number and arrangement, of the amino-acids accounts for the particular property of the individual proteins. In some instances generic traits in the protein family are definitely recognizable. Thus the albumins differ from the globulins by two familiar reactions; their behavior toward water and a half-saturated solution of amonium sulphate. Albumins are soluble in both; while globulins are precipitated in both. Now it happens that albumins contain no glycin while globulins show a constant, though small, percentage thereof. That the traits above mentioned depend upon the presence or absence of this particular amino-acid and nothing else is too much to be asserted in the present state of our knowledge. But that some such difference must account for the properties mentioned is a safe statement. Gelatin, elastin, and the various coccoon silks are all very rich in glycocoll; while casein, vitellin and the characteristic proteins of the cereal grains are equally rich in glutamic acid; and so on.

The significance or adequacy of a protein in nutrition, we shall find later is likewise to be attributed to its composition of amino-acids. The composition of the milk proteins compared on the one hand with that of ox muscle and on the other with the gliadin of wheat is given in the following table.

TABLE 81.—COMPARATIVE COMPOSITION OF PROTEINS

Amino-acids	Gliadin[336] (wheat), per cent.	Casein[336] (milk), per cent.	Lactalbumin[336] (milk), per cent.	Ox[340] muscle, per cent.
Glycocoll	....	....	....	4.0
Alanin	2.00	1.50	2.50	8.1
Valin	3.34	7.20	0.90	2.0
Leucin	6.62	9.35	19.40	14.3
Prolin	13.22	6.70	4.00	8.0
Phenylalanin	2.35	3.20	2.40	4.5
Aspartic acid	0.58	1.39	1.00	10.6
Glutamic acid	43.66	15.55	10.10	22.3
Serin	0.13	0.50	?	?
Tyrosin	1.50	4.50	2.20	4.4
Cystin	0.45	?	?	?
Histidin	1.84	2.50	2.06	4.5
Arginin	2.84	3.81	3.23	11.5
Lysin	0.93	7.61	9.16	7.6
Tryptophan	1.00	1.50		
Ammonia	5.22	1.61	1.32	1.07
	85.68	66.92	58.27	102.87

The casein of woman's milk and that from cow's milk have been partially hydrolyzed by Abderhalden and Langstein[255] with the results given in Table 82.

When the proteins are absorbed in the form of amino-acids they are carried by the portal circulation to the liver where they may be immediately deaminated: Or perhaps upon some signal to the liver from the blood, as in the case of glycogen, they are permitted to pass the hepatic cells unchanged and to reach the tissues where growth is taking place.

TABLE 82.—AMINO-ACIDS FROM CASEIN (ABDERHALDEN AND LANGSTEIN)

	Cow's casein, per cent.	Woman's casein, per cent.
Glycocoll	0.0	0.0
Alanin	0.9	1.2
Valin	1.0	1.3
Leucin	10.5	8.8
Prolin	3.1	2.85
Phenylalanin	3.2	2.8
Glutamic acid	11.0	10.95
Aspartic acid	1.2	1.0
Tyrosin	4.5	4.58

Deamination.—In the adult the amount of nitrogen in the urine is the measure of the quantity of protein eaten. The curve of nitrogen excretion ascends rapidly reaching its maximum in two to four hours, continues high for some time, depending upon the total quantity ingested and then recedes slowly. Lusk[464] has shown in his work on the dynamic action of protein that the effect upon heat production of a heavy protein meal runs almost parallel with the curve of total nitrogen excretion. The dynamic effect being due to the stimulating effect of oxy-acids resulting from deamination (p. 545) it follows that this curve represents at the same time the rate of deamination. Hoobler's[208] results upon the dynamic effect of high protein feeding in the infant show that it is not the protein retained for growth but only that part whose nitrogen appears in the urine which affects the heat production. The two sets of observations taken together go far to prove that in their contribution to growth of new tissue the protein fragments are at no time deprived of their nitrogen. Deamination proceeds very rapidly where little protein is being retained; for the extra glucose formed from amino-acids (administered as such or as meat) appears as rapidly in the urine of a diabetic dog, as if an equivalent amount of glucose itself were given. In all probability there is no delay—no time required for selection of those fragments which will be used for growth and those which will be deaminated in the rapidly growing organism. The rate of growth does not depend upon the amount of protein fed; but upon the growth impulse, which is a matter of inheritance, and upon vitamines. When the amount of protein available for growth just equals the capacity of the growth impulse to handle it the best progress is made (p. 790). Anything over this amount is surplusage and will be deprived of its nitrogen.

Deamination may take place by hydrolysis or by oxidation. The former is illustrated by the following reaction for alanin:

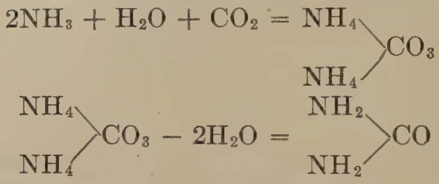
$$\underset{\text{Alanin}}{CH_3\text{-}CH\cdot NH_2\cdot COOH} + HOH = \underset{\text{Lactic acid}}{CH_3\cdot CH\cdot OH\cdot COOH} + NH_3$$

By oxidation the reaction would run thus:

$$\underset{\text{Alanin}}{CH_3\cdot CH\cdot NH_2\cdot COOH} + O = \underset{\text{Pyruvic acid}}{CH_3\cdot CO\cdot COOH} + NH_3$$

Probably both methods are used—the former has been proved to occur in the case of certain amino-acids of the aliphatic series and the latter for certain of those of the aromatic series. This is not to say that either one method or the other must be chosen by the tissues. The course of disintegration followed probably depends upon the oxidative capacity of the tissue whose province it may be to effect the changes, as well as upon the presence of enzymes which mediate them.

Ammonia split off is rapidly converted to urea[393] thus:



$$2NH_3 + H_2O + CO_2 = \begin{matrix} NH_4 \\ NH_4 \end{matrix}\!\!>\!CO_3$$

$$\begin{matrix} NH_4 \\ NH_4 \end{matrix}\!\!>\!CO_3 - 2H_2O = \begin{matrix} NH_2 \\ NH_2 \end{matrix}\!\!>\!CO$$

This reaction takes place by preference in the liver, where also the major part of the deamination occurs, but may take place in the muscles and probably in other organs. Formerly it was believed that deamination was effected in the alimentary wall and in support of this was cited the fact that the mucous lining of the intestine is richer in ammonia than any other tissue of the body, and the further fact that the portal vein contains more ammonia than the hepatic vein. But Folin[130] furnished evidence opposed to this view when he developed the fact that the ammonia of the portal vein comes mainly from the large intestine and appeared to be formed from putrefactive processes. Moreover the arrival of amino acids at the tissues themselves has now been fully demonstrated.

Synthesis of Proteins.—Details regarding the constructive side of metabolism (anabolism) in the body are almost wholly lacking. We lose sight of the amino-acids when they arrive at the tissues. We can only measure the end result in terms of nitrogen retention, or in terms of growth in mass, or of individual compounds like albumin, globulin and the like. Something has been learned however of the possibilities of protein synthesis under the influence of enzymes from physico-chemical studies, and since one of the clearest instances of the synthetic or reversible action of proteolytic enzymes concerns the protein of milk, it may be discussed briefly here.* It is not unreasonable to hope that from such beginnings we may one day be able to visualize the construction of tissue materials in the infant from the food of its mother's breast.

A fundamental advance of recent years in our knowledge of enzymes is the realization that these all-important substances are not pure catalyzers in the sense that they do not enter at all into the reaction and are not used up to any degree. Proteolysis takes place automatically in pure solution in distilled water as has been shown by

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* The statements of facts in this discussion are taken from Robertson's recent work on the "Physical Chemistry of the Proteins," New York, 1920, a work which may be highly commended to the reader for a much more adequate presentation.

Taylor[421] and Robertson.[369] Trypsin and pepsin merely hasten the reaction, but they do so not by their presence only but by addition of themselves as real chemical agents in the system. Since these enzymes are in all probability proteins they are subject to hydration and dehydration as any other proteins. Further they are known to suffer loss of activity in water solutions, which may be explained by hydrolysis and to be capable of precipitation by methods which are clearly dehydrating. It is possible therefore that each of them may exist in at least two modifications—one more hydrated than the other. The activity may vary with this condition of the enzyme itself as well as with the concentration of the substrate and of the products of proteolysis. Evidence has already been given of the union of proteolytic enzymes with the substrate (p. 719). If a more characteristic type of combination be desired, it may be found in the fact brought out by Vernon[450] that egg albumin very seriously interferes with the action of trypsin upon any other protein, and does so by actual union with the enzyme.

Nevertheless enzymes partake to some degree of the characteristics of pure catalyzers. As such they must accelerate the velocity of reaction equally in both directions. That is, if in a proteolytic enzyme-substrate system a point of equilibrium exists at which a portion of the substrate remains unaltered, then in a pure solution of proteolytic products and enzyme there must be a tendency to rebuild the substrate out of the products. This result was anticipated from the physico-chemical laws of catalysis before it was actually seen.

A number of instances of reversible enzyme action are now known for all classes of foodstuffs. The clearest instance perhaps among proteins is that observed by Robertson[368] in the action of pepsin upon casein. A peptic digest prepared by neutralizing 400 c.c. of N/10 KOH with casein and adding ½ gm. fresh pepsin (per liter) was kept at 40°C. Heating to destroy the enzyme, filtering and concentrating six times at 70°C., a clear brown syrup was obtained free of casein and paranuclein (p. 718). To 70 c.c. of this syrup 30 c.c. of a concentrated solution of Gruebler's pepsin, *puriss sic*, which had previously been filtered, were added and the mixture set aside at 40°C. in the presence of an excess of toluol to prevent bacterial infection. Within two hours a thick white precipitate had formed. After 48 hours this was filtered off, purified, dried and analyzed. *It gave all the reactions of paranuclein.* Gay and Robertson[149] investigated the product by specific immunity tests. They found that the products of complete peptic hydrolysis were toxic and had no antigenic property. The pepsin of Gruebler also was non-antigenic. But paranuclein originally produced and the product of synthesis just described both gave specific antibodies which reacted interchangeably with either substance. A genuine protein synthesis had therefore been effected by pepsin out of the products of proteolysis from casein.

Further study by Robertson of this remarkable instance of protein synthesis (which should be of special interest to students of nutrition in infants) developed the facts: (1) That the velocity of reversion does not bear the same relation to the concentration of ferment that the velocity of hydrolysis does; and that as a consequence the equilibrium between the protein and its products was altered by the pepsin; (2) That by heating an anhydrous form of the ferment could be produced which inhibited hydrolysis and favored synthesis; and (3) That the high concentration of enzyme necessary to produce synthesis is explained by the greater proportion of the anhydrous form which it contains. Robertson supposes that a high concentration of split products would result in the production of a larger proportion of the anhydrous form of the enzyme, but that upon removal of the enzyme from the system by adsorption or otherwise it would regain its original hydrolytic action. In some such fashion, conceivably, a cycle of reactions may occur, the enzyme being utilized over and over, now for hydrolysis, now for synthesis. By temporary mechanical or chemical separation and localization of the synthesizing forms of these enzymes the living organism thus may build up the amino-acids into new proteins characteristic of the several tissues.

Retention of Protein in the Infant.—The only measure of protein synthesis for the entire organism is the amount of nitrogen retained from the food. In the adult the normal state is a condition of equilibrium between the intake and output of nitrogen; but in the growing organism this condition would be abnormal. Indeed, in many kinds of illness the child continues to retain nitrogen even when losing weight. In the adult the factors of diet and physiological condition which influence protein retention are well-known, the most important being the "sparing action" of carbohydrate and the protein condition of the organism. In the infant several additional factors must be considered.

The Growth Impulse.—This is the name given to the physiological tendency of youthful protoplasm to lay hold of germane materials and transform them into its own substance. The normal growth rate characteristic of a species is the measure of the growth impulse. Naturally it is very different for different species; a puppy dog, for example, doubling its birth-weight in two weeks, while it requires six months for a human infant or a calf to accomplish the same relative increase. In general the concentration of proteins in the mammary secretion in different species is proportional to the rate of growth; but the food cannot be said to cause the rate of growth; it only supports it. Much has been learned of late regarding the influence of vitamines and of internal secretions upon the rate of growth and it is clearly evident that in the future normal growth must be defined in terms of these factors as well as of energy, adequacy of protein, salts, etc. The water soluble B, for example, is known to influence the appetite[363] and thus to increase the intake of food. But appetite is the expression of need for materials to be supplied the tissues not the stomach, and hence the vitamine must influence the rate of their utilization beyond the alimentary wall. Thyroid secretion influences the rate of development,[164] *i.e.*, of histogenesis and the almost miraculous transformation of a cretin under the influence of thyroid administration is but a magnified image of its normal influence in the development of the nervous system. Without this effect the growth impulse misses the mark, so to speak, and fails to effect the normal transformation of food materials into tissue elements.

Instances might be multiplied of particular food constituents and of internal hormones each of which must play its part in the symphony of chemical changes if an harmonious product which we recognize as the normal child is to be produced. The growth impulse is therefore not a single factor but a group of factors working together to create a demand for building materials. It originates for the individual when male and female nuclear elements unite in the act of fertilization, and from this moment forward to the end of development its imperial decrees are transmitted through countless generations of chromosomal agents which guide the structural changes to their completion, some of them finishing their work early, some, especially in the brain, not finishing until middle adult life.

Rated in terms of a unit of mass the growth impulse is greatest before birth and immediately thereafter. Orgler[331] gave expression to this fact in the formulation known as Orgler's law that the younger the infant the greater (relatively) is its power of assimilation of protein. In a study of nineteen newborns up to 14 days of age Mensi[299] confirmed this law, finding the average retention to be 48 per cent. of the protein ingested. The range in 14 cases was from 3 to 71 per cent. The power of assimilation was not less in artificially nourished infants than in the naturally nourished. The nitrogen balance the first five to eight days may be negative depending upon the function of the breast; but in the second week it changes to positive and the retention ranges from 40 to 60 per cent. of the intake.[256]

The rate of retention (measure of growth impulse) diminishes in the first five months to one-third the value which it may have the first two weeks. The following comparison is made by Schwarz.[396]

TABLE 83.—NITROGEN RETENTION ACCORDING TO AGE OF BREAST-FED INFANTS (SCHWARZ)

Author..........	Schwarz	Michel I	Michel II	Keller	Michel and Peret	Schwarz	Rubner and Heubner
Age............	4 days	5 days	11 days	2 months	3 months	4 months	5 months
N intake per kilogram......	0.685	0.407	0.425	0.430	0.354	0.286	0.205
Retention per kilogram......	0.552	0.314	0.343	0.194	0.156	0.143	0.048
Percentage.....	81.0	77.2	81.0	45.0	44.0	50.0	23.0

With Michel's second case and Keller's subject the intake per unit of weight is the same but the percentage retained in the former is nearly twice as great as in the latter. Orgler gives the average percentage retained up to 14 days as 78.3 per cent., from two to three months 40.8 per cent., at five months 23.1 per cent.

Protein Condition of the Organism.—The second factor relates to the demand for protein which may be created by a period of deprivation. It was shown independently by Peters[378] in Rubner's laboratory and by Murlin[316] in Lusk's laboratory that the avidity with which the adult organism retains nitrogen is greater the greater the previous losses by it have been. That the same is true of the infant has been demonstrated by L. F. Myer[301] and by Keller.[86] The former gave a healthy ten-months infant following a period of adequate nourishment a diet containing considerably less than the child's requirements of energy and of nitrogen. The results are presented in Table 84.

TABLE 84.—ADAPTATION TO LOWER NUTRITIVE PLANE BY A TEN-MONTHS INFANT (L. F. MEYER)

Period	Food	Urine	Feces	Balance
	N per diem in grams			
I. Full diet	5.124	3.2	0.4439	+1.447
	5.124	3.486	0.4439	+1.194
	5.124	3.269	0.4439	+1.411
II. Falling weight	1.932	2.616	0.152	−0.836
	1.932	2.146	0.152	−0.366
	1.932	1.984	0.152	−0.204
	1.932	1.663	0.152	−0.117
III. Constant weight	1.922	1.541	0.183	+0.197
	1.922	1.590	0.183	+0.148
	1.922	1.394	0.183	+0.344
	1.922	1.226	0.183	+0.513

After cutting down the intake of nitrogen the infant body adapted itself rapidly to the lower plane of nutrition and within five days without further change of diet advanced from a daily loss of 0.836 gm. to a gain of 0.197 gm. and continued to gain until there was a retention of 0.513 gm. daily. Meyer observed that the loss of mineral substances was reduced at the same time.

TABLE 85.—ADAPTATION TO A LOWER NUTRITIVE PLANE BY A THREE-MONTHS INFANT (KELLER)

N in food	N in urine	N in feces	N, balance
0.766	0.793	0.135	−0.161
0.719	0.710	0.067	−0.057
0.747	0.491	0.124	+0.132

Keller's infant, a child of three months, was changed from a diet of one-third milk to one containing 750 gm. of water, 50 gm. gluten flour and 51 gm. cane sugar. He took 651, 615 and 622 gm. of the mixture on three successive days with the result shown in Table 85. Here again the destructive metabolism was gradually reduced until a negative balance was changed to a positive balance.

The mechanism by which a quick adaptation of this sort is accomplished may be explained in the following manner. The energy demands are paramount. So long as the supply of protein is in excess of the needs a portion of the protein is deaminated and utilized for energy. In the adult where protein is needed only for repair and growth in isolated places the inevitable breakdown of protein may be turned to the service of the energy needs more readily, although even here there comes a time when deamination is checked as the tissues become more hungry for replenishment and fragments discharged from one tissue may be placed in requisition for the benefit of others. In the growing organism this latter adjustment takes place much sooner simply because all tissues are demanding amino-acids as building material. The energy needs are then met by mobilization of fat from the reservoirs of the body and the vital structures are spared. Such restriction of energy needs as may be brought about by limitation of muscular movements is the only resource on the energy side of the metabolism and this adjustment is often made even in the infant. Amino-acids of one type can be made from the amino-nitrogen of another by union with the oxyacids which are formed in the intermediary metabolism of carbohydrate. The animal organism is limited however in this capacity to manufacture amino-acids, and this leads us to consideration of the next factor in determining nitrogen retention.

The Biological Value of the Protein.—The ideal food protein for construction of new tissue is one which contains all the essential amino-acids. Since milk and eggs are designed by nature to supply a sufficient variety of amino-acids for synthesis of all the proteins of the various tissues it would be expected that the young organism could accomplish its growth most economically upon food materials of this kind. For the mammalian young milk should by the same token be much more valuable than the eggs of birds. Experience fully confirms this expectation. Not only so: Milk of the species to which the young belongs is more valuable than that of an alien species.

It is universally conceded that the very young infant at least can add to its weight upon mother's milk more economically than upon cow's milk. For illustration the results of Benjamin[35] may be cited. This observer followed the nitrogen balance in a "nearly normal" infant in successive periods on breast-milk, then breast-milk plus an increasing amount of skim milk and finally two-thirds whole milk and 5 per cent. sugar. For 100 gm. increase in weight the retention of nitrogen on breast-milk was 3.7 gm., on breast-milk and skim milk 4.5 gm., and on the two-thirds whole milk and sugar 5.3 gm. The last two diets contained nearly double the amount of nitrogen supplied by the breast-milk alone. A unit of growth is therefore attained more economically on breast-milk than on cow's milk. Some of the nitrogen retained from cow's milk apparently does not become organized into protoplasm. This is confirmed by the fasting experiments of Schlossmann and Murchauser[390] who found that the total loss of nitrogen in a fast of 18 to 72 hours was always greater from infants previously fed on cow's milk than from those fed at the breast. In the old terminology of Voit there was a greater amount of "circulating" or unorganized protein from cow's milk.

For the adult the biological value of the protein is rated according to the least amount capable of maintaining nitrogen equilibrium when the energy requirements are fully covered by non-nitrogenous foods. Experiments of this kind by Thomas,[426] Ziterer,[471] and Steck[412] revealed the fact that muscle protein is slightly better than casein for this purpose. Thomas compared these two proteins with many others of both animal and vegetable origin and arranged a scale of values based upon the percentage of repair nitrogen capable of being furnished by each. It will be most interesting to learn whether the biological values of these proteins for maintenance of the adult remain the same for growth of the infant. There is evidence for the protein of potato that such is not the case; for while Thomas ranks potato proteins at 83 in a scale of 100, in which casein and ox-muscle stand at the head, and the proteins of maize and wheat at only 29.5 and 39.5, McCollum[289] and his coworkers have found that potato protein *for growth of the white rat* is of no greater value than those of the cereal grains. Inasmuch as other authors,[195,375] have fully confirmed the high rank given by Thomas to potato protein as a material for maintenance of nitrogen equilibrium, it seems clear that the same proteins cannot equally satisfy the two requirements. If this statement should be confirmed for other proteins the reason for such a difference in biological value for the two purposes in question, would according to McCollum, lie along the following lines. When an animal is fasting the amino-acids of the blood are kept remarkably constant through the sacrifice of muscle tissue as a source of cleavage products. Whether an animal is fasting or taking an incomplete protein it is still necessary that certain organs continue to form special products like the hormones which are necessary to correlate the physiological activities of the several tissues. In the formation of such bodies there is a demand for special amino-acids, tyrosin for example for adrenalin, tryptophan presumably for thyroxin, etc. For maintenance of growth in certain other tissues (sex cells, hair, nails, epithelial cells in the intestine, etc.), which apparently never cease to grow, other special requirements arise. Each of these special drafts upon the circulating aggregate of amino-acids leaves certain others which may be supplemented by those of an incomplete (for growth) protein in such a way as to make a fairly adequate protein for maintenance. When growth takes place, however, this supplementary relationship shown by the protein of potato, by gelatin[316] and by some other proteins cannot be of great importance, for the endogenous breakdown of protein is then very slight compared with the total requirement. Muscle, gland, brain and all must be provided for. Nitrogen equilibrium alone would not be growth, and could only lead to one-sided development.

We are not yet in a position to give a numerical rating to very many of the different food proteins as growth material. The method adopted by Benjamin for the proteins of cow's milk and human milk is capable of improvement so that the same amounts of proteins would be used with an adequate supply of energy in infants of the same age or in the same infant successively, and a numerical valuation obtained not only from milk proteins but for various others made equally digestible by the infant. A beginning in terms of growth for the white rat using the quotient of growth in relation to food protein eaten instead of in relation to food protein (nitrogen) retained, as in Benjamin's method, has been made by Osborne, Mendel and Ferry[341] who calculated that to make the same gain in the same time under the conditions of maximum efficiency 24 per cent. more protein and 20 per cent. more food (energy) were needed when the protein was casein of cow's milk than when it was lactalbumin. This is information of the most useful kind for infant feeding. The authors point out, however, that "when an animal is restricted to such a quantity of protein that a maximum gain of body weight is made per unit of protein eaten, it grows at less than the normal rate. A longer time therefore is required to make a given gain of weight, and consequently more food is needed for maintenance than if growth had not been thus delayed." Economy in nutrition during growth, they conclude, depends upon a correct adjustment between the proportion of protein in the diet and the total energy supplied. If it is stated that a child makes a perfectly satisfactory gain when the protein of its food constitutes a certain percentage (see Hoobler[208]) of the total calories, it is not to be inferred that a greater gain would not have been induced had the protein been used less economically, or that "food" would be wasted if a greater intake of energy were permitted. It must first be determined whether rapid gain in weight or more economical gain in weight is the more desirable.

The newer knowledge of nutrition which has been gained from recent studies on laboratory animals should now be made the useful knowledge of nutrition through the application of the principles involved to infant feeding. Unfortunately we cannot yet infer quite safely that the proteins will have exactly the same relative values for growth of the human young as for the white rat. It has often been surmised, for example, in agreement with the observations just cited, that the reason why human milk is more efficient in producing growth than cow's milk is because of its higher percentage of lactalbumin. The evidence in support of this view however is by no means complete. For while Osborne and Mendel[338] observed better growth in rats when lactalbumin was used as the source of protein with "protein free milk," starch, butter-fat and lard, than when casein was so used, McCollum[289a] and his associates did not obtain this result when lactalbumin and casein were used separately to supplement the protein of peas, and they explain the excellent results of Osborne and Mendel with lactalbumin by the high proportion of nitrogen derived from their "protein free milk." Emmet and Luros[114] on the other hand display growth curves quite up to the normal with 10 per cent. of lactalbumin, added to a mixture which contained no "protein free milk" and find that purified lactose supplements quite as well or better than the "protein free milk." They dissent therefore from the explanation offered by McCollom, holding that lactalbumin is a complete protein "in the sense that it does not lack any of the nitrogenous cleavage products essential for growth." On the human side we have the observations of Grosser[163] who found that when the albumin was precipitated out of human whey and the casein and fat of cow's milk added to the protein-free whey, the artificial mixture supported growth in infants quite as well as when the entire whey was used. The inference from this work was that the non-precipitable parts of whey (and probably the salts) were more important than the proteins in securing the satisfactory results so often reported for "whey adapted" milk. The experiments, it must be admitted were not crucial as to the relative values of the two major proteins of milk; but they indicate that better controlled tests must be resorted to before it can be safely inferred that lactalbumin is the limiting factor when poor results are obtained with cow's milk.

Many attempts have been made in the history of artificial feeding to supplement the proteins of cow's milk with proteins of various cereals, and benefit has often resulted. From what we know of the biological value of such proteins for growth of laboratory animals it may be inferred that the nutritional benefit observed is traceable to other properties than those of the contained proteins.[288] Even gelatin has been used in this way and an infant who failed to gain on a sufficient supply of mother's milk has been observed[162] to put on weight when gelatin with oat meal gruel was added to the breast milk. But gelatin is wholly unsuited to this purpose on account of its irritating effect upon the stomach and at best it can spare but a fraction of the body protein.[317]

In conclusion of this question of the biological value of mother's milk as compared with cow's milk for growth of the human offspring it may be added that under certain circumstances practically the whole quantity of protein in mother's milk may be retained in the child's body while with cow's milk this is never the case, a considerable part always being destroyed and eliminated by the urine. There is no justification for the claim that the proteins of breast milk are better adapted for assimilation than those of cow's milk.[85] It seems rather that the other constituents of the food exercise a favorable influence on protein retention.

Often it has been surmised that the "extractive nitrogen" of mother's milk, being more plentiful than in cow's milk, is responsible for the better retention. This can only be true if the extractive nitrogen is of such a kind that it can be built up into tissue proteins, and if the difference between the two milks in this or these constituents is significant. Among the extractive substances occurring in milk the following have been determined quantitatively: Amino-acids, urea, uric acid, creatinin and creatin. Recent analysis by Denis[99,100] using methods which were devised for corresponding analyses of blood give for the two milks the following composition of average values in milligrams per 100 c.c. of milk.

TABLE 86.—NON-PROTEIN CONSTITUENTS OF HUMAN AND COW'S MILK (DENIS)

	Total non-protein nitrogen	Urea nitrogen	Amino-acid nitrogen	Uric acid nitrogen	Preformed creatinine nitrogen	Creatin nitrogen
Mother's milk.............	28.8	12.01	5.81	2.7	1.3	2.6
Cow's milk.................	26.2	9.2	4.2	1.5	1.1	2.3

The figures for human milk are a little higher throughout. The undetermined non-protein nitrogen however is distinctly higher for cow's milk. Some of these undetermined bodies are the purin bases and possibly polypeptids in very small amount. Only further knowledge will permit of a decision whether the extractive nitrogen of human milk is of higher nutritive value than that of cow's milk. If the undetermined nitrogen should prove to consist mainly of polypeptids and the like and only to a slight degree of the purin bases the apparent slight advantage of mother's milk from higher amino-acid nitrogen would be wholly overcome. The uric acid, creatinin and creatin cannot be supposed to confer any nutritive properties and despite very positive reports by Grafe[159] that urea can contribute a protein-sparing property to the diet of the dog and swine a real nutritive value is not conceded[4] by other investigators. Hence we must look to the amino-acids and simple combinations thereof to explain any supposed superiority of extractive nitrogen in human milk.

The Amount of Protein Fed.—There seem to be very few observations on the effect of different quantities of protein in the diet upon protein (nitrogen) retention which were sufficiently controlled to limit the comparison to a single variable. As we shall see in the sections immediately following an adequate energy supply is one of the conditions of protein retention and there is some evidence that with an excessive supply the retention of proteins is more favorable than on a mere sufficiency. The energy supply in different periods with different quantities should therefore be the same. An experiment by Hoobler[208] substantially fulfills this requirement and will therefore be used for illustration. The subject was a healthy boy of two months whose heat production (p. 636) on low and high protein feeding was being determined simultaneously with the protein retention. Table 87 presents the average daily metabolism of the food stuffs as determined by the calorimeter and the nitrogen determinations. The points of special interest to us at this time are: (1) that the average intake of energy was substantially the same in the two series; (2) that the proportion of protein in the food of the second series was so much increased that it reduced the caloric intake from fat and carbohydrate from 290 to 198 calories—considerably less than was being *metabolized* from this source in the first series; (3) nevertheless the metabolism of fat and carbohydrate remained about the same, 234 calories instead of 225, and since the food did not supply sufficient nonprotein calories, the remainder was drawn from the body; (4) the protein metabolized in the first series was 7.6 gm. out of 9.9 gm. supplied or 77.3 per cent., in the second 15.6 gm. out of 31.1 gm. supplied or 54.3 per cent.; (5) the protein retention for growth, however, does not include all of the remainder for there was a considerable loss in the feces. Another table given by Hoobler shows that this loss in the first period was on the average 0.440 gm. and in the second 1.43 gm., leaving for retention 1.86 gm. or 18.8 per cent. of the intake the first period and 14.07 gm. or 45 per cent. of the intake the second period.

TABLE 87.—METABOLISM ON LOW AND HIGH PROTEIN (HOOBLER)

	Total food calories			Protein							Fat and carbohydrate					
				In food			Metabolized				In food		Metabolized			
	In-take	Metabolized	Per cent. of intake	Calories	Grams	Per cent. of total	Calories	Grams	Per cent. of protein in intake	Per cent. of total food intake	Calories	Per cent. of total	Calories	Per cent. of intake of F and CH	Per cent. derived from Fat	Per cent. derived from CH
Low protein diet, average of five hours sleeping....	331	255	77.0	40.7	9.90	12.3	33.9	7.6	77.3	13.3	290.3	87.7	225	86.7	14.8	85.2
High protein diet, average of 10 hours sleeping.....	326	304	93.2	127.7	31.1	40.3	69.37	15.6	54.3	22.9	198.2	59.7	234	118.5	46.6	53.4

This experiment therefore is a clear-cut demonstration of the influence of a high protein intake as contrasted with a low protein intake upon nitrogen retention. The food throughout was cow's milk given in ordinary dilutions with sugar for the low protein period and given as albumin milk in the high protein period. Probably all of the protein retained was not organized into protoplasm at once; for as we have seen (p. 794) cow's milk leaves for a time a considerable amount of protein in circulation, and the depressing effects of the high-protein feeding described by Hoobler were doubtless due to this circulating portion. Another series of observations which may be used to illustrate the influence of protein intake upon protein retention is that of Talbot and Gamble[420] on a single infant between five and seven months of age. Their results may be summarized briefly as follows:

TABLE 88.—INFLUENCE OF PROTEIN INTAKE ON PROTEIN RETENTION (TALBOT AND GAMBLE)

Period	Age, months	Weight at start, kilograms	Food N	N in urine	N in feces	N retained grams
1	5¼	4.3	4.79	2.876	0.895	+1.02
2	5¾	4.42	9.31	5.816	1.28	+2.21
3	6	4.66	11.06	7.482	1.475	+2.10
4	6½	4.93	13.91	8.065	1.92	+3.92
5	6¾	5.06	17.01	11.893	3.477	+1.64

Each period in this series consisted of three days so that the infant had a better chance to adapt himself to the new level of protein intake. Up to the fourth period the food was well utilized and the nitrogen retention increased. The authors state that in the fifth period when the nitrogen in the stools was greatly augmented the child appeared to be "on the verge of a digestive upset." The steady increase in the urinary nitrogen exhibits in a striking way the effort of the organism to rid itself of the nitrogen which was surplus above its requirements. The inference from both series of observations is perfectly clear, that for prolonged nitrogen retention and *organization into tissue* a very moderate quantity of nitrogen is more economically managed than a large quantity (see preceding section).

The purposes of nitrogen in the growing organism are summarized by Rubner[379] as, (1) replacement, (2) growth, and (3) combustion.* The requirement for the first is small but must be met before growth can take place. Protein in excess of the infant's capacity to organize it into tissue may be used for combustion and the nitrogen will appear in the urine. When the capacity to deaminate protein and eliminate the nitrogen is reached the toxic or depressant effect is seen.

Armsby[18] employs a useful method for defining the efficiency of protein for growth of farm animals which might well be adapted to the investigation of proteins for growth of children on mixed diet. He states that, "the percentage of digestible protein of the feed which is retained in the body of the growing animal is not in itself a measure of the efficiency of the animal organism in converting feed protein into body protein, since the proportion retained is affected both by the magnitude of the protein supply in the feed and by the energy content of the ration. . . . The percentage utilization (efficiency) of the feed protein in the physiological sense, as distinguished from the percentage retention, is the ratio between the body protein thus stored up and the least amount of feed protein in excess of the maintenance requirement which is necessary to support this growth under the most favorable conditions, especially as to energy supply. Suppose for example, that an animal three months old actually has the capacity to store up daily 1.23 pounds of protein per 1,000 pounds live weight, and that it has been shown that it can just reach this capacity on a ration supplying two pounds of digestible protein per day. Deducting 0.5 gm. pound for maintenance, there remains 1.5 pounds of protein in the ration out of which is produced 1.23 pounds body protein. The utilization (efficiency) is therefore 1.23 ÷ 1.5 = 82 per cent. If, on the other hand, it was found that 2.5 pounds of protein had to be supplied in the ration in order to bring the gain in protein up to capacity of the animal, the percentage utilization would be only 1.23 ÷ 2.0 = 62 per cent. while if the maximum growth could be secured with 1.73 pounds of digestible proteins, the utilization (efficiency) would evidently be 100 per cent.”

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* Wendt[463] recognizes a fourth value of protein which he calls the *thesauric* or storage value. Protein for this purpose may remain unmetabolized as a depot for future use. It is not apparent from any of the published researches on infants how great this quotum may be.

In the experiment of Talbot and Gamble cited above the total energy intake was fairly constant throughout but the proportion of carbohydrate (sugar) calories to the total was higher in the second period than in the first and third and still higher in the fourth when the maximum retention was attained. Probably, as we shall see below, the higher carbohydrate was responsible in part for this result.

The Specific Influence of Carbohydrate on Nitrogen Retention.—It has long been known that nitrogen retention is favored by the presence of carbohydrate in the diet. E. Voit and Korkunoff[455] found that nitrogen equilibrium in the dog could be maintained on the following quantities of nitrogen (meat) in terms of the starvation nitrogen taken as 100.

With meat alone	–368
With meat and fat	–157–193
With meat and carbohydrate	–108–134

It has many times been shown with the adult human subject that nitrogen equilibrium can be established at a level below that of the starvation excretion of nitrogen by ingestion of a diet rich in carbohydrate.[406, 252, 426, 71] This effect of carbohydrate is due to a “sparing action” upon the body protein whereby the latter is preserved against the katabolic processes of the body. Landergren[252] believes that when a condition arises in the body when it has no carbohydrate at its disposal the body must prepare it by breakdown of body protein, the amino acids after deamination being synthesized into blood sugar. The constancy of the blood sugar in prolonged starvation after the store of glycogen has been exhausted speaks in favor of this hypothesis. The giving of carbohydrate therefore spares that amount of protein from destruction which would be necessary to keep up the blood sugar to its normal level. Fat does not do this since it cannot be transformed into sugar. Ringer[366] in analyzing these conditions distinguishes three component parts in the protein metabolism: (1) The "minimal nitrogen requirement" which represents the amount of body protein katabolized during specific nitrogen starvation when the body receives all of its requirements in the form of carbohydrate or carbohydrates and fats in equal caloric quantities. For the adult man this amounts to about 4 gm. nitrogen daily and corresponds to Rubner's "wear and tear quota;" (2) the "dextrose nitrogen" which represents the amount of protein katabolized in excess of the minimal requirement in nitrogen starvation when the caloric requirement is not covered by carbohydrate from food but may be covered by body fat or fat in the food; and (3) the "complementary nitrogen" which represents the amount of protein katabolized for the sake of energy in excess of (1) and (2) under any circumstances but particularly when large quantities of protein are fed. The excessive destruction of protein noted in the preceding section would be "complementary nitrogen" in this sense.

Another explanation of the sparing action of carbohydrate has been given by Shaffer[403] to the effect that glucose in normal concentration holds in check the action of intracellular proteolytic enzymes and consequently when carbohydrate is lacking and the sugar (or glycogen) concentration in the cells falls an inhibition is removed and the enzymes become correspondingly more active. This hypothesis has received no support from actual observation on the organism. While it is probably true, as Landergren held, that the body has a specific need for carbohydrate and can satisfy its need from katabolized protein, this cannot be the only explanation of a sparing action; for as the writer[317] has shown the katabolism of body protein increases sharply in the presence of abundant carbohydrate when the sparing action of gelatin is suddenly withdrawn. Now the latter sparing action, as was demonstrated in the same investigation, is not due to the glucose which it can yield in intermediary metabolism, but to its protein nature; hence, we may distinguish this type which may be called a true replacement sparing from that type effected by carbohydrate and which may be called a dynamic type, or possibly after Shaffer, a preservative type.

All of which however concerns only one aspect of metabolism—the destructive side. Carbohydrate does unquestionably retard disintegration of tissue protein, whichever be the method. This in itself favors a nitrogen balance. But does it not at the same time or quite independently, aid the constructive side? What is the significance of lactose in the mammary secretion of all animals? First as to the facts.

Keller[226] was the first to demonstrate this influence of carbohydrate in the infant. With a six-month's child he obtained the following incisive results with maltose.

TABLE 89.—INFLUENCE OF MALTOSE ON NITROGEN RETENTION OF AN INFANT (KELLER)

Food	N in food	N in urine	N in feces	N retained, grams	Per cent. of intake
One-fourth cow's milk 75 grams maltose...	2.04	1.3225	0.239	0.478	23.5
Whole milk..........	3.832	3.189	0.185	0.458	11.9
Whole milk plus 75 gm. maltose.........	3.830	2.744	0.347	0.739	19.3

While the sugar increases peristalsis and causes a greater loss of nitrogen in the stool, in the third period the reduction of nitrogen in the urine more than compensates for this, leaving a greater net retention than when no maltose was given. The favoring influence of lactose on the nitrogen metabolism of the infant is illustrated by an experiment of Talbot and Hill[419] on an infant six months of age. Starting with a cow's milk mixture containing 5.63 per cent. lactose, the amount of sugar was increased successively to 7.32 and 9.93 per cent. then was dropped to 9.16 per cent. The daily nitrogen retention increased *pari passu* with the lactose from 2.06 to 2.27 and 3.16 gm. then fell off to 1.81 gm. Unfortunately the intake of nitrogen and of total calories was not kept constant, so that while the inference of a real favoring action is probably correct it is not a matter of demonstration. Talbot and Hill surmise that a possible explanation of the increased retention is the utilization by the fecal bacteria of lactose instead of protein thereby leaving more protein for absorption; but such an explanation need not be invoked unless there is demonstrably less nitrogen in the stool. Moreover, this would not be a true sparing action except for the bacteria. Weinland[461] proved quite conclusively with rabbits that lactose absorbed diminishes protein katabolism and Sommer[408] observed that it was more efficacious with young than with older animals. Studying the influence of sugars upon the growth of suckling pigs Wilson[465] found that skimmed cow's milk reinforced with lactose caused a more rapid gain in weight than cow's milk and Lusk,[276] commenting on this experiment, points out the importance of an isodynamic replacement of fat by milk sugar in infant feeding.

An experiment which puts this principle into effect is that of Hellesen[180] who placed an infant five months of age first upon a diet containing an abundance of carbohydrate and later replaced 50 grams of the carbohydrate (cane sugar) with 25 gm. of butter—a nearly isodynamic equivalent. He studied both the respiratory and the protein metabolism. The results in average daily quantities are given in Table 90.

There is a striking difference in the two periods. On the high carbohydrate not only is there a better retention of nitrogen for growth—there is also a more economical use of the carbon of the food and consequently of the potential energy. The benefit extends indeed to the inorganic constituents, water and sodium. The negative balance of the latter on the high fat diet is explained by the loss of this element through the stool (p. 782). The two non-nitrogenous food-stuffs therefore are by no means of equal value in the nutrition of the infant.

TABLE 90.—COMPARISON OF CARBOHYDRATE AND FAT IN THEIR INFLUENCE ON RETENTION IN AN INFANT (HELLESEN)

Period	Food					Retention in per cent. of intake			Retention in grams	
	Nitrogen	Fat	Lactose	Cane sugar	Starch	Nitrogen	Carbohydrates	Calories	H_2O	Na
I........	4.306	4.7	29.7	56.4	6.2	25.2	18.1	13.0	50	0.195
II........	3.966	25.0	29.9	6.4	6.2	8.1	2.4	2.6	28	−0.09

Does the sparing effect of carbohydrate on protein waste sufficiently explain its favoring influence in growth? That has been the usual assumption, and certain facts connected with the excretion of creatin which will be mentioned beyond appear to favor this view. But another possibility must be admitted; namely, that in the construction of new tissue proteins certain strategic amino-acids may be the more readily combined, fitted into place, or even built-up out of oxyacids furnished by the carbohydrate and amino-nitrogen extravagantly furnished by the liver. Attempts have been made to prove the synthesis of protein from salts of ammonium[158] under the favoring influence of carbohydrate, but not with complete success. Nascent amino-nitrogen however while still in the H-N-H grouping might be an altogether different matter.[241]

Katabolism of Protein.—Thus far we have considered the probable steps by which protein of the food is built up (anabolized or synthesized) into tissue proteins, and the factors which govern the retention of protein for this purpose. We must now turn our attention to further details concerning the processes by which protein of the food or of the tissue is broken down (katabolized) and eliminated from the body. In the adult these two major changes are quantitatively equal, the protein condition being maintained at an approximately constant level. In the growing organism anabolism naturally predominates, being, as we have seen (p. 791), most intense in early infancy and gradually though not constantly diminishing with age to maturity of size. Nevertheless katabolism is always present.

The katabolism of protein is measured in the gross and to some extent in detail by the nitrogen sulphur and phosphorous of the urine. Folin[128] in 1905 made a useful distinction by dividing the protein katabolism into two parts: The endogenous representing tissue metabolism the products of which tend to remain constant, and the exogenous representing metabolism of protein in the food, the products of which vary with the amount of protein ingested. The former is represented by creatinin and neutral sulphur and to a less extent by uric acid and ethereal sulphates; the former preeminently by urea and inorganic sulphates. Folin illustrates this distinction by mean of the following table showing the composition of the urine on high and low protein feeding.

TABLE 91.—NITROGEN AND SULPHUR FRACTIONS IN THE URINE OF ADULTS ON HIGH AND LOW PROTEIN (FOLIN)

	High protein		Low protein	
	Grams	Per cent. of total	Grams	Per cent. of total
Total N	16.3	....	3.60	
Urea N	14.70	87.5	2.20	61.7
Ammonia N	0.49	3.0	0.42	11.3
Uric acid N	0.18	1.1	0.09	2.5
Creatinin N	0.58	3.6	0.60	17.2
Undetermined N	0.85	4.9	0.27	7.3
Total SO_3	3.64	....	0.76	
Inorganic SO_3	3.27	90.0	0.46	60.5
Ethereal SO_3	0.10	5.2	0.10	13.2
Neutral SO_3	0.18	4.8	0.20	26.3

The creatinin and ammonia nitrogen and the neutral sulphur are nearly the same in absolute amounts on both diets. The ammonia as we now know is constant because the requirements for neutralization of acid radicles happened to be the same in the two instances. The creatinin is constant because the two diets were taken by the same individual. The neutral sulphur is constant because the destruction of tissue containing cystin was the same. The urea nitrogen, undetermined nitrogen (containing amino-acids, polypeptids and purin bases) uric acid nitrogen and ethereal sulphate sulphur show the greatest differences in absolute amounts because they are dependent upon the amount of protein delivered to the tissues by the digestive system. Fractions of the nitrogen not considered by Folin in this basic study are the creatin, purin bases and amino-acids singly or in combination.

Nitrogen Partition in the Urine of Infants and Children. 1. *Urea.*—The main circumstance in the metabolism of infants and children which may be supposed to alter the distribution of nitrogen of the urine to its various constituents, is the retention of protein for growth. For the first few days of life, however, the elimination is not yet normal as will be noted especially when uric acid is considered. According to Reusing[361] the percentage of urea in the urine of breast-fed infants increases from the first to the third days and then gradually falls while in wet-nursed infants and those fed from birth on cow's milk the maximum percentage falls on the first day and then declines.

The explanation lies in the varying volume of urine as was shown by this author by injection of methylene blue into the circulation at birth or into the mother before birth. The elimination of the dye was parallel to the elimination of urea. In proportion to weight the excretion of urea is not quite parallel for breast-fed and artificially-fed infants. Reusing gives the following figures in grams per kilogram.

Days	1	2	3	4	5	6	7
Breast-fed	0.0189	0.085	0.173	0.166	0.257	0.288	0.292
Soxhlet-milk	0.1067	0.135	0.231	0.195	0.226	0.213	0.298

The higher absolute elimination for the first four days in artificial feeding is due to the larger intake of nitrogen.

In percentage of the total nitrogen the urea nitrogen in the first few days is high because of the low total nitrogen.[405] By the time the kidney is functioning fully it may be as low as 60 per cent. of the total in breast-fed infants.[452] In a five-months breast-fed infant Schwarz[396] found that the urea nitrogen made up 72 to 75 per cent. of the total, but when put on artificial feeding the same child eliminated 78 per cent. of the total as urea nitrogen. Vogt states that the urea quotient (percentage of total nitrogen) varies between very narrow limits in the infant's urine so long as the food has a normal composition. He demonstrates the influence of retention upon the distribution between urea and "rest" nitrogen (including all the other fractions save ammonia) and sums up his observations in these terms. When the protein metabolism is so ordered as to serve for replacement of losses or manufacture of new tissues it leads to a relatively high rest nitrogen, but any protein in excess of this requirement is eliminated as urea. The writer[318] has shown that the increasing retention of nitrogen by the pregnant dog for growth of the fetuses causes a progressively lower percentage of urea and a correspondingly higher percentage of undetermined nitrogen, and has found lower percentages of urea nitrogen than normal likewise in the late stages of pregnancy of the woman.[319] In fact retention of nitrogen for growth of any sort, if large enough in proportion to the total nitrogen will always produce this effect because a portion of the nitrogen which under ordinary circumstances (in the adult) would be split-off from amino-acids as ammonia and eliminated either as such or as urea is resynthesized, while those fractions which represent the endogenous metabolism (creatinin, uric acid in part, and undetermined nitrogen in part) show as a consequence a relative increase.

For normal children above the weaning age the distribution of nitrogen in the urine has been studied by Johnston and Veeder.[218] The results may be introduced here because of their interest as regards the urea excretion.

TABLE 92.—NITROGEN PARTITION BY GRAMS AND PERCENTAGE FOR NORMAL CHILDREN (JOHNSTON AND VEEDER)

Date and age	Amount	Specific gravity	Total nitrogen	Am-monia nitrogen	Urea nitrogen	Crea-tinin nitrogen	Creatin nitrogen	Uric acid nitrogen	Per cent. of total nitrogen					
									Urea	Am-monia	Crea-tinin	Crea-tin	Uric acid	Unde-termined
"Standard" Diets														
I. 21 months														
10/27–28	750	1.012	4.480	0.173	3.941	0.050	0.037	0.060	87.8	3.9	1.1	0.8	1.3	5.1
10/28–29	550	1.018	4.425	0.176	3.852	0.047	0.027	0.050	87.0	4.0	1.1	0.6	1.1	6.2
Average..........	650	1.015	4.45	0.175	3.897	0.049	0.032	0.055	87.4	3.9	1.1	0.7	1.2	5.7
II. 9 years														
11/ 9–10	440	1.030	7.936	0.354	.....	0.165	0.112	0.069	....	4.5	2.1	1.4	0.9	
11/10–11	410	1.030	8.064	0.325	6.717	0.162	0.098	0.052	83.5	4.0	2.0	1.2	0.6	8.7
Average..........	425	1.030	8.000	0.340	6.717	0.164	0.105	0.060	83.5	4.2	2.0	1.3	0.8	8.2
Creatinin-Free Diets														
I. 28 months														
11/29–30	860	1.007	3.968	0.214	3.332	0.049	0.079	0.089	84.0	5.4	1.2	2.0	2.2	5.2
11/30–12/1	860	1.012	3.347	0.259	2.778	0.045	0.064	0.099	83.0	7.7	1.3	1.9	2.9	3.2
12/1–2	705	1.014	3.676	0.213	3.120	0.052	0.074	0.077	85.0	5.8	1.4	2.0	2.1	3.7
Average..........	755	1.011	3.663	0.229	3.077	0.049	0.73	0.088	84.0	6.3	1.3	2.0	2.4	4.0
II. 6 years														
11/29–30	770	1.013	4.975	0.205	4.041	0.081	0.064	0.081	81.0	4.1	1.6	1.3	1.6	10.4
11/30–12/1	1140	1.007	4.800	0.213	3.760	0.100	0.038	0.101	78.3	4.4	2.1	0.8	2.1	12.3
12/1–2	610	1.013	4.733	0.200	.....	0.095	0.024	0.073	....	4.2	2.0	0.5	1.5	
Average..........	840	1.011	4.836	0.201	3.90	0.092	0.042	0.083	80.0	4.2	1.9	0.9	1.7	

The control of the diet, the manner of collection of the urine and the general management of the observations in this series were nearly ideal and may well be imitated in future work of this character. The "standard" diets given were selected in accordance with the dietary habits of well-fed children, consisting of milk, oatmeal, graham crackers, egg, beef-stew, bread, butter and prunes. The amount of protein given was graded according to age groups as follows:

Children 20 months to 36 months	42 gm.	— 6.7 gm. N.
Children 3 years to 6 years	52.6 gm.	— 8.0 gm. N.
Children 6 years to 10 years	58.0 gm.	— 9.0 gm. N.
Children 10 years to 14 years	60–65 gm.	—10.0 gm. N.

The creatinin-free diet consisted of—	whole milk	200 c.c.
	cream, 20 per cent	200 c.c.
	two eggs	
	malted milk	200 gm.
	water to	1000 c.c.

Each 100 c.c. of this mixture contained approximately 150 calories; 30 to 40 calories per kilogram of body-weight were given and the total amount for the day divided into five portions. Each 100 c.c. contained approximately: 7.5 gm. fat; 6 gm. protein; 15.5 gm. carbohydrate.

The average percentages for 13 children between 19 months and 12 years on standard diets, and for eight children between 29 months, and 14 years of age on creatinin-free diets are compared as follows:

	Urea	NH_3	Creatinin	Creatin	Cr. and $Cr._2$	Uric acid
Creatinin-free diets	83.7	4.1	2.0	1.0	3.0	2.2
"Standard" diets	83.7	4.6	1.6	1.2	2.8	1.3

The range of the urea percentage as of other fractions is well represented in Table 92. Comparing these with the percentages found by Folin[126, 127] from adult subjects kept on a non-meat diet containing 18 to 19 gm. nitrogen, we note that the average for urea is some 5 per cent. lower, because of retention. It may be safely stated that the urea nitrogen in infancy, especially of breast-fed children, will be from 5 to 8 per cent. less than in the adult who is kept on an adequate diet containing a proportionate amount of nitrogen. For children up to puberty the urea normally will run from 3 to 5 per cent. (of the total nitrogen) below that of adults.

It is probable that the reduction of urea following the use of malt extract first observed by Keller[224] and ascribed by Vogt[452] to the contained carbohydrate is in reality due to increased retention induced by the water-soluble vitamine contained in the malt.[19, 179]

Urea from its quantitative relations in the urine must be regarded as the most important end product of metabolism. Many theories as to the mode of its formation in the body have been propounded; but the most probable one is that of Schmiedeberg[393] which is described on page 788; namely, its formation from ammonia split off from amino-acids by oxidation or hydrolysis. That urea can be formed from ammonium salts fed to infants[441] just as when fed to animals or injected into the circulation or perfused through the liver is now abundantly proved. The same and other experiments, especially those of Von Schroeder,[456] prove that the liver is the chief seat of its formation. More recent work, however, demonstrates with equal clarity that other tissues can produce urea when the liver is excluded[321a] from the circulation or removed[456a] altogether from the body. Fiske and Sumner[124] have found that the accumulation of urea per unit of mass of blood and tissues after intravenous injection of amino-acids is as great (in the absence of shock) when the liver and other abdominal viscera are excluded from the circulation as when they are in their normal relations. Analysis of blood from the liver and from the hind legs of dogs from which the entire alimentary canal was removed, by Taylor and Lewis[421a] showed only a slightly higher concentration of urea in the former than in the latter, from which they conclude that the formation of urea is a function of all the tissues. The experiments of Van Slyke and Meyer[448] and of Jansen[216] on the other hand support the view that the liver is the organ especially responsible for the katabolism of those products of digestion not utilized for tissue construction. The first-named authors show that amino-acids injected into the circulation are absorbed by the tissues, but that they disappear much more rapidly from the liver than from other organs. "The amino-nitrogen content of this organ may be doubled by an injection of amino-acids into the general circulation, and yet return to normal within two or three hours." Whereas the muscles reach the saturation point when they contain about 75 gm. of amino-acid nitrogen per 100 gm. of tissue, the liver "continually desaturates itself by metabolizing the amino-acids that it has absorbed and consequently maintains its power to continue removing them from the circulation."

2. *Ammonia.*—The absolute amount of ammonia in the urine of very young infants on the basis of weight is high as compared with adults. The reason for this was shown by Czerny and Keller[87] to be the relatively high fat of the infant's food even on breast-milk. But on the percentage basis the ammonia nitrogen is even higher and this is explained by the low total nitrogen due to retention *as well as* to the high fat. Amberg and Morrill[15] had under observation a normal breast-fed infant four weeks of age in two periods of six days each. During the first period the infant received a fairly high protein diet and in the second a mere maintenance diet with low protein and low fat. The ammonia nitrogen the first period was 8.1 per cent.; in the second period in spite of the low fat it was 18.3 per cent. of the total. In the first to third months of breast-fed infants Vogt noted ammonias as

high as 29 per cent. of the total, and 20 per cent. has frequently been reported.

The true explanation of the influence of fat upon ammonia excretion was given by Steinitz[414] and was soon confirmed by Freund. The soaps prevent the absorption of a portion of the alkalies and their place in the urine is taken by ammonia (Table 80). Freund made more complete analyses than did Steinitz and found the phosphoric acid increased in proportion to the diversion of ammonia. High ammonia in the infant's urine in the relative sense therefore is not always to be looked upon as a sign of acidosis or even of aciduria but rather as a lack of alkali (alkalopenia). Indeed according to the latest conception[174] high ammonia in the urine is proof of the capacity of the organism to neutralize acid or to replace alkali diverted alsewhere, and is not proof of an actual acidosis in the sense of too much acid remaining in the circulation as by retention of phosphates in nephritis.

With older children one other factor comes into play in connection with the excretion of ammonia; namely, the nature of the ash of the food. With foods like cereals and meats which contain an acid ash more ammonia will be excreted in the urine than with foods containing an alkaline ash. The capacity of the body to care for acid radicles in this way shows a wide margin of safety and there is little danger under ordinary circumstances of overtaxing it.[284] The real criterion is the alkali reserve of the blood (p. 814). In Table 91 it is seen that wide differences in the protein intake do not affect the output of ammonia in the absolute sense, which is the only sense in which the ammonia in the urine is significant as a sign of acid excretion; while in Table 92 it may be noted that the excretion of this fraction is fairly constant in the absolute sense for any given child and, owing to the general similarity of diets, is fairly constant in the relative sense in the different children.

Because night urine approaches a little more nearly the character of starvation urine it would be expected that more ammonia would be present. Powis and Raper[355] have noted that this is true in children.

3. *Amino-acid Nitrogen.*—From the existing state of our knowledge regarding the fate of amino-acids once they reach the blood stream (p. 738), it is clear that they do not remain long in the circulation even if no tissue has any special avidity for them; for, having a relatively high diffusion coefficient, they can pass the kidney readily just as they pass the intestinal wall. For example, Van Slyke and Meyer[446] recovered from the urine 1½ gm. of d-l-alanin one-half hour after injecting 12 gm. of this substance directly into the circulation. Feeding dogs with 10 gm. doses of glycocoll, alanin and glutamic acid added to a diet of bread and milk, Dobrowolskaja[101] found alanin in the urine oftener than the others. This corresponds with the experience of Lusk[275] who found that while the nitrogen of 20 gm. of glycocoll is completely converted to urea by the phloridzinized dog, only about 70 per cent. of i-alanin is so converted. It follows, there fore, that certain amino-acids can pass the kidney much more readily than others, or else are much less readily disposed of in metabolism.

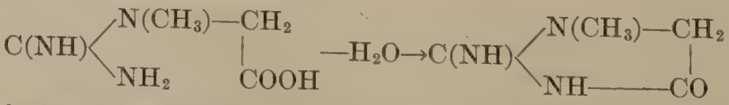
Whether the age of the subject would affect the result of such experiments has, so far as the writer is aware, not been determined. Determined by reliable methods the absolute amount of monamino-acid nitrogen in the urine of a normal adult on a mixed diet is from 0.15 to 0.30 gm. daily or 1.5 to 3.0 per cent. of the total nitrogen.[265, 193a] On a milk diet the fraction of undetermined nitrogen, which includes chiefly the amino-acid, and polypeptid nitrogen, is considerably higher than on an ordinary mixed diet.[272]

In infancy the amino-acid nitrogen of the urine has often been reported as very much higher than this. Thus Simon[405] found as much as 12 per cent. in the urine of newborns, and Bahrdt and Edelstein[26] 0.244 to 0.284 gm. daily or 10 per cent. of the total in the case of an eight months atrophic child. In older children 9 to 14 years, Hadlich and Grosser[166] report 13 to 30 mg. per 100 c.c. of urine or 2 to 11 per cent. of the total. A partial explanation at least of these higher amounts in infancy and childhood will be found in the considerations which account for the low urea (p. 803).

4. *Other Amino-bodies.*—In this paragraph may be summarized the very meager information regarding the excretion of polypeptid nitrogen, oxyproteic acid, hippuric-acid, nitrogen, etc., in children. Simon in the research already cited has reported up to 12 per cent. of the total nitrogen as polypeptids in the urine of newborns and has noted the presence in small amount of oxyproteic acid. He is inclined to ascribe their occurrence to the poor supply of enzymes in consequence of which the infant organism is obliged to content itself with an incomplete cleavage of protein at the alimentary wall or in the endogenous reduction.

Hippuric acid was reported by Simon as present in the urine of two newborns in quantities of 5 to 39 mg. and Amberg and Helmholz,[17] reversing the earlier results of Amberg and Morrill and Amberg and Knox were able to demonstrate it constantly in urines of both breast-fed infants and bottle-fed in amounts not exceeding 1 per cent. of the total nitrogen.

5. *Creatinin.*—This body is produced by some vital activity of muscular tissue. It is derived from creatin, a constituent of all muscle cells by a process of dehydration:



$$\mathrm{C(NH)}\left\langle\begin{array}{ll}\mathrm{N(CH_3)-CH_2} & \\ & | \\ \mathrm{NH_2} & \mathrm{COOH}\end{array}\right. -\mathrm{H_2O}\rightarrow \mathrm{C(NH)}\left\langle\begin{array}{lr}\mathrm{N(CH_3)-CH_2} & \\ & | \\ \mathrm{NH}\text{———} & \mathrm{CO}\end{array}\right.$$

Perfectly fresh muscle contains very little creatinin if any, but as used by man for food in the form of meats it has more creatinin than creatin, especially if the meat is thoroughly cooked, when little if any creatin is left. Creatin ingested as such[374] or injected subcutaneously[278] is only partly converted to creatinin, the remainder apparently being stored in the muscles as creatin. When the food is entirely free of creatin or creatinin the excretion of creatinin is nearly constant for any given individual from day to day, being independent of muscular work,[402] of heat production[342] and the quantity of protein food[133] (Table 91) or any other discoverable condition external or internal except the mass of muscular tissue and possibly its condition of tonus.[349] The number of milligrams of creatinin nitrogen per kilo of body weight excreted by an individual kept for several days on a creatin or creatinin free diet, is known as the creatinin coefficient.[402] For adult males it lies in the neighborhood of 8.0 and, for females[433] at about 5.8. For the pregnant female near term it is lower[321] because of the low creatin content of the fetus, uterus, etc.

The creatin content of the muscles of the newborn child is 0.07 per cent.[373] as compared with 0.3 per cent. for the adult. This is in agreement with observations on other animals,[304] and has been given as an explanation of a lower creatinin excretion in infancy and childhood.[244] It turns out, however, that the creatinin coefficient of infants and children on meat-free diet is often quite as high or higher than that of the adult female and frequently passes the average given by Shaffer as the value for the male. The following table compiled from Amberg and Morrill[14] and Funaro[143] gives some idea of the range of the coefficient for very young, healthy infants at the breast.

TABLE 93.—CREATININ EXCRETION BY YOUNG INFANTS

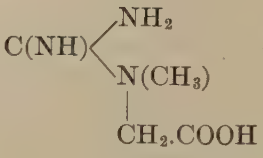
Author	Age, days	Weight	Nitrogen as creatinin in urine	
			Milligrams per kilogram	Per cent. of total N
Amberg and Morrill.....	7	3093	5.46	2.98
	10	3463	7.78	3.06
	10	4033	6.71	2.56
	13	3100	9.7	2.78
	14	2723	9.94	3.61
	Months			
Funaro...............	1½	3500	5.00	
	2	4000	5.25	
	2½	4300	6.5	
	3	4000	7.6	
	3	4380	7.12	

In percentage of the total nitrogen the creatinin nitrogen for the newborn child is apparently somewhat higher than it is for older children (Table 92). Values considerably higher than those of Johnston and Veeder have been found by Gittings and Pemberton[154] who had under observation two healthy children 33 and 40 months of age respectively, fed for eight days on meat-free food. The excretion was 0.078 and 0.089 gm. creatinin-N daily which was 2.2 and 2.7 per cent. respectively of the total, while the creatinin coefficient was 7.04 and 8.04.

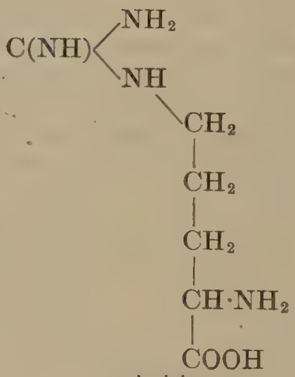
Conditions known to reduce the creatinin excretion in infants and children are: amyotonia with a coefficient of 1.47 according to Gittings and Pemberton and 4.0 according to Sprigg;[413] infantilism[291] of the Herter type with coefficients in the neighborhood of 4.0 or 5.0; cretinism[161] and rickets.[395] Prolonged feeding with creatin-free food has been thought to reduce the creatinin metabolism in adults,[367] though it is difficult to reconcile this observation with modern views regarding the origin of creatin.

Conditions known to produce the opposite effect of increasing creatinin metabolism are: myotonia,[376] diabetes[245] and fevers.[365b]

6. *Creatin.*—The two most probable sources of creatin are (1) arginin and (2) cholin or betaïn. Comparing the formula of creatin with that of arginin we see that there is an unmistakable relationship.

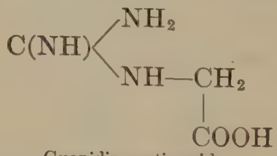


Creatin



Arginin

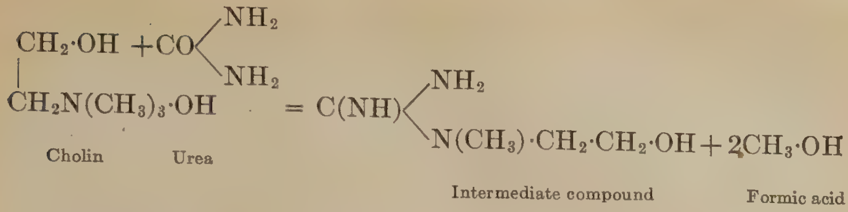
By a typical oxidation there may be produced from arginin guanidin acetic acid which requires only a simple methyl condensation, the like



Guanidin-acetic acid

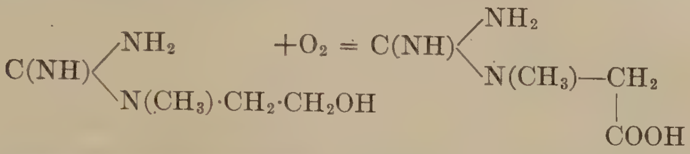
of which is well authenticated, for transformation into creatin.

Experimental support for this conception is found in the work of Jansen,[217] who made creatin determinations in the muscles of the two legs of a frog, one made tonic by various means, the other not. The stimulated muscle always contained at once more creatin and less arginin than the other. Injection of arginin into the jugular vein of rabbits results, according to Thompson,[427a] in a clearly demonstrable increase of creatin of the skeletal muscle amounting to 14.5 per cent. of the injected arginin. Such injections made subcutaneously are more effective (for increasing the total excretion of creatin) if methyl citrate is combined with arginin carbonate.[427b] The origin of creatin from cholin is thus conceived by Riesser.[363]



$$\begin{array}{l} CH_2{\cdot}OH \\ | \\ CH_2N(CH_3)_3{\cdot}OH \end{array} + CO\begin{array}{l} \diagup NH_2 \\ \diagdown NH_2 \end{array} = C(NH)\begin{array}{l} \diagup NH_2 \\ \diagdown N(CH_3){\cdot}CH_2{\cdot}CH_2{\cdot}OH \end{array} + 2CH_3{\cdot}OH$$

By oxidation and the loss of a molecule of water from the intermediate body creatin is formed.



$$C(NH)\begin{array}{l} \diagup NH_2 \\ \diagdown N(CH_3){\cdot}CH_2{\cdot}CH_2OH \end{array} + O_2 = C(NH)\begin{array}{l} \diagup NH_2 \\ \diagdown N(CH_3)\text{—}CH_2 \\ \qquad\qquad\quad | \\ \qquad\quad\;\; COOH \end{array}$$

By injecting cholin neutralized with HCl Riesser was able to demonstrate an increase in the creatin content of rabbits muscles and an increased elimination[364] of creatinin in addition to a fair amount of creatin, in the urine. Betaïn which is closely related to cholin had a similar though less marked effect.

That creatin of the urine is not of necessity derived from creatin of the muscles is inferred by Benedict and Osterberg[34] from their discovery that the muscles of a phloridzinized dog which had suffered large losses of creatin were nevertheless richer in creatin than those of a normal dog. Creatin is not found in the urine of normal adults except during starvation or undernutrition, and it quickly disappears from the urine when either carbohydrate[70] or fat[160, 291] is added so as to cover the requirements for energy. Any pathological condition which produces a wasting of tissue causes its prompt appearance in the urine. Conditions such as these, as we have seen, cause an increase also in the elimination of creatinin.

It is now generally agreed[373, 131, 97, 244] that creatin occurs as a regular constituent of the urine of all normal children, particularly of the night urine.[131, 97] It would serve little purpose in the present state of our knowledge to give extensive data on the amount excreted by children, for it has recently come to light, (1) that infants unlike adults excrete creatin ingested with the food;[145] and (2) that milk contains significant quantities of creatin (Table 86, p. 797). Denis and her colleagues[97, 98] have demonstrated an apparently close relationship between the creatin excretion and the protein intake, the excretion "being large when quantities of creatin-free protein are ingested, decreasing and in some cases disappearing when a very low protein diet is given." These results were confirmed in a general way for infants by Gamble and Goldschmidt[145] by varying the amount of whole milk given. They were led to suspect, however, that the creatin of the cow's milk might be sufficient in amount to account for the variations produced in the urinary creatin. This proved to be the case, and the variations in urinary creatin could be produced quite as well by additions of whey as by additions of whole milk. Definite proof of the influence of protein is therefore wanting at this time.

Vegetarian children were observed by Folin and Denis to excrete from 8 to 18 mg. of creatin in 100 c.c. of urine while children on ordinary mixed diets eliminated up to 250 mg. daily. On milk diets (called "creatin-free") the amount was 150 to 160 mg. daily (see also Table 92).

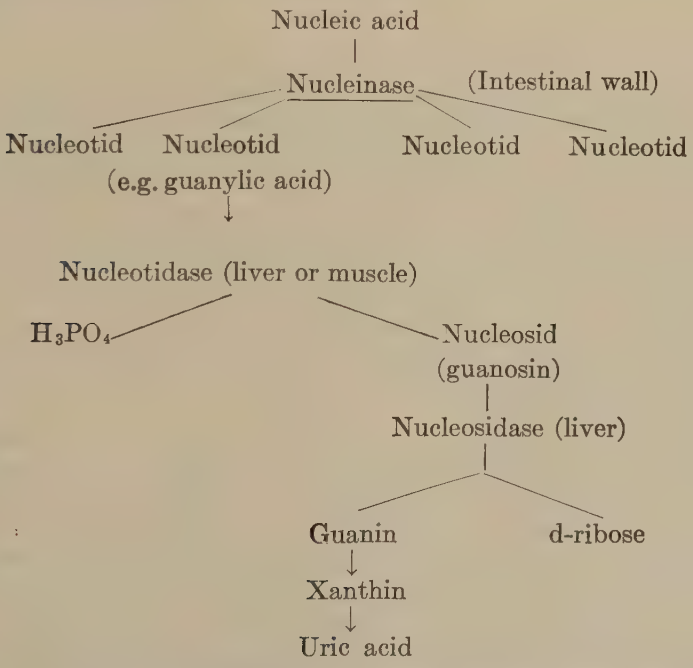
The rôle of carbohydrate in driving creatin from the urine is not so obvious as it seemed a few years ago;[298] for it now appears that fat can accomplish the same end, only less readily.[291,160] It will be necessary to control the effect both of fat and of protein before an assured position can be taken regarding the relation of creatin in the urine to the sparing effect of carbohydrate.

Creatinuria coincides often but not invariably with aciduria. This was pointed out originally by Krause and Cramer,[245] and was supported by Underhill[438] upon the basis of observations on the effects of a corn and oats diet in rabbits. An acid urine was produced by this diet and creatin was invariably found as an accompaniment, whereas on a diet of carrots alkaline urines were obtained and no creatin. Underhill inferred a condition of acidosis from the occurrence of a highly acid urine. However, since an actual depletion of alkali was not demonstrated it is not certain that a true acidosis existed. Besides, Gamble and Goldschmidt[145a] were unable to discover any change in the amount of creatin eliminated by an infant when 100 c.c. N/10 HCl was administered with the milk and the p_H of the urine was changed from 6.4 in a control period to 5.9. Sodium bicarbonate likewise failed to lower the excretion of creatin although the p_H was raised to 8.3. The only experiments which appear to corroborate the original idea of a coincidence, and, therefore, probably a causal relationship, between acidosis and creatinuria are those of Sawyer, Stevens and Baumann.[382] These authors produced a real change in the alkali reserve (bicarbonate of the plasma) by administration to children of a high fat and low carbohydrate diet. In all their experiments there was a pronounced increase in the creatinuria during the period of acidosis, although the creatinuria occurred at times also when there was no acidosis.

7. *Uric Acid.*—Coincident and equally significant with the discoveries leading to the resolution of the ordinary proteins into their constituent amino-acids (p. 783) have been those which revealed the structure of nucleic acids. For nucleic acids combined with ordinary proteins as nucleo-proteins, enter into the composition of every cell nucleus in the body. When we consider that the nuclei not only transmit the hereditary traits which work themselves out in our mature bodies but constitute also the very center of the metabolic and trophic activities in many if not in all types of cells, we see how important this knowledge may one day become in the elucidation of the vital processes. Particularly should this field be of interest to those concerned with problems of growth and development of the infant. The

subject can be given but a small fraction of the attention it deserves in this place.

The rate of destruction of nucleic acid and therefore of nucleoproteins in the body can be followed by analysis of the urine for uric acid and the purin bases. Recall briefly a few of the underlying chemical facts. Nucleic acids are polymeric compounds of smaller acid bodies known as nucleotids. A nucleotid consists of a carbohydrate combined on the one hand with phosphoric acid and on the other with a pyrimidin base, such as urocyl or cytosin, or with a purin base, such as adenin or guanin. It requires an enzyme known as a *nucleinase* to split a nucleic acid into its component nucleotids. Phosphoric acid may be split off from a nucleotid by a *nucleotidase*, leaving the carbohydrate and the base as a nucleosid. Finally a *nucleosidase* may break the bond between carbohydrate and purin base thus completing the destruction of a nucleo-protein. The first enzyme nucleinase exists in the pancreatic juice (p. 731); the others are found in the various tissues (liver, muscle, etc.). The phosphoric acid is excreted in combination with some basic element; and the carbohydrate is burned; but the purin base if not used for synthesis must be eliminated. Meanwhile it is subjected to oxidation. Adenin when oxidized becomes hypoxanthin, guanin becomes xanthin and either of the last-named bodies may be further oxidized to uric acid. The following schema will serve to visualize these successive stops.*



Since the casein of milk is a phospho-protein containing para-nucleo-protein or nucleo-albumin (p. 718) which yields on further cleavage only phosphoric acid and albumin but never purin bases, it follows that the infant must be able to manufacture its own purin bodies for the construction of true nucleic acids. It follows further that the uric acid and purin bases of the infant's urine are practically all of endogenous origin.

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* For a complete discussion see "The Nucleic Acids" by Walter Jones, 2nd ed. N. Y., 1921.

The quantity of uric acid eliminated in the first few days of life has been studied by reliable methods by Reusing,[369] Orgler,[332] Niemann,[323] and Schloss and Crawford.[385] Schloss and Crawford compare their own results with those of Reusing in the following table.

TABLE 94.—THE URIC ACID ELIMINATION IN THE NEWBORN

Day	Reusing (6 cases)	Schloss and Crawford (8 cases)
1	41.1 mg. in 24 hrs.	29.3 mg. in 24 hrs.
2	41.1 mg. in 24 hrs.	75.5 mg. in 24 hrs.
3	83.1 mg. in 24 hrs.	91.0 mg. in 24 hrs.
4	39.5 mg. in 24 hrs.	62.3 mg. in 24 hrs.
5	56.6 mg. in 24 hrs.	42.7 mg. in 24 hrs.
6	46.3 mg. in 24 hrs.	36.4 mg. in 24 hrs.
7	37.3 mg. in 24 hrs.	36.1 mg. in 24 hrs.
8	....	36.0 mg. in 24 hrs.
9	....	29.3 mg. in 24 hrs.

The excretion rises rapidly to a maximum on the third day then goes down steadily until it becomes stationary at a level of about one-half that at which it started. Considering that an adult man weighing 70 kg. will eliminate in 24 hours only 300 to 600 mg. of endogenous uric acid this excretion by an infant of perhaps 3.5 kg. particularly the first few days is very high. The peak of the elimination curve coincides with the most frequent occurrence of uric acid infarcts long known in the kidney of the newborn. Reusing was of the opinion that the urate deposits in the medullary portion of the kidney which make up the infarcts were caused by the high purin metabolism, an acid urine and particularly by the great concentration of the urine due to a deficient fluid intake.

Niemann[323] suggested that the high nucleo-protein metabolism manifested by the high elimination, accompanied by cast formation (infarcts), was the result of an excessive destruction of leukocytes. Schloss and Crawford went further and demonstrated an inverse relationship between the leukocyte count and the total purin excretion. Particularly was this true in cases of late ligation (two to five minutes after the pulsations of the cord had ceased). Although there is no absolute proof of a causal relationship here, the indications are that the high excretion of uric acid is due to leukocytolysis and that this is greater on the second and third days of life in infants which have received a liberal amount of blood from the placenta. The uric acid of the blood itself is highest on the third day after which it falls steadily to the eighth day.[400]

Schloss and Crawford gave conclusive proof that the uric acid excretion the first few days was not traceable to the ingestion of cellular material in the colostrum and this has been confirmed by Birk.[41] The purin content of the colostrum proved to be only in the region of 6 mg. per 100 c.c. of fluid at the highest. That the infant is capable of transforming nucleic acid, were it present in the food, may be seen in the experiments of Niemann in which after a control period he gave 0.5 to 3.0 gm. of sodium nucleinate in the food. For one of these, an infant eight months of age, the results were:

Table 95.—Influence of Sodium Nucleinate on the Purin Metabolism of an Eight Months Infant (Niemann)

Period	Uric acid, milligrams, urine	Purin bases, milligrams	Purin bases, milligrams, feces
II. Fore period	81.5	10.68	42.0
III. Fore period	93.8	10.0	40.5
3.0 gm. Na. Nucleinate in food.	260.6	10.3	74.2
After period	108.1	13.1	51.2

Nearly 10 per cent. of the extra material ingested was removed by way of the urine as uric acid, none of it as purin bases, except a small amount which augmented this fraction in the stool.

Orgler[332] maintains that the uric acid output of the infant is considerably higher on artificial feeding than on breast feeding.

Table 96.—Excretion of Uric Acid and Total Purin Bodies by the Same Infants on Breast and Artificial Feeding (Orgler)

	Case I		Case II		Case III		Case IV	
	Uric acid	Total purin bodies*	Uric acid	Total purin bodies	Uric acid	Total purin bodies	Uric acid	Total purin bodies
Breast feeding	130.1	137.0	125 0	159.3	153.6	153.6	153.4	195.7
Artificial feeding	201.2	244.6	247.2	288.3	227.6	242.4	204.7	248.9
Increase in per cent	54.0	78.7	99.0	82.0	50.0	40.0	33.0	28.0

* Total purin bodies are calculated to the basis of uric acid.

This greater excretion on cow's milk Orgler proved was not the consequence of a larger ingestion of protein, and this fact is confirmed by the observations of Talbot and Gamble. Moreover, we have recently learned (p. 797) that cow's milk contains on the average less uric acid among the extractive substances than does mother's milk. Orgler found, however, that carbohydrate has a marked effect to reduce the purin metabolism whenever it causes a greater retention of nitrogen; otherwise not. Quite probably there is utilization of the endogenous purin bodies in a case of this kind for construction of new nucleoproteins and the more economical effect of mother's milk upon the purin metabolism must be referred to those unknown factors which account for more rapid growth under these circumstances.

In older children the uric acid of the urine is exogenous in origin as well as endogenous. Johnston and Veeder (Table 92) report measurably more uric acid from children on so-called creatin-free diets than on their standard diets. The reason for this is not obvious.

8. *Purin Bases.*—The excretion of nitrogen in this form by the newborn infant is exceedingly small. Only on a single day in one of the cases studied by Niemann was the weight of purin bases more than 10 mg. The results of Schloss and Crawford and of Birk are in agreement with this. The table below from Schloss and Crawford is modified to include their data on the purin base nitrogen separately from the total purin nitrogen.

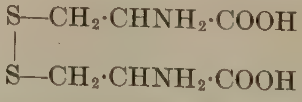
TABLE 97.—EXCRETION OF PURIN BASE NITROGEN, TOTAL PURIN NITROGEN AND TOTAL NITROGEN BY THE NEWBORN. AVERAGE OF FIVE LIGATION CASES (SCHLOSS AND CRAWFORD)

Day	Total N milligrams	Purin base N	Total purin N	Ratio of total P. N. to total N
1	172	5.5	24.7	1:7
2	241	10.8	40.4	1:6
3	332	9.7	43.9	1:7
4	271	7.0	27.0	1:10
5	327	5.1	18.5	1:17
6	342	7.2	19.0	1:18
7	274	4.0	16.1	1:17
8	333	3.4	15.1	1:22

The excretion of purin bases runs approximately parallel to the total purin and therefore to the uric acid. The rapid fall in the ratio is due to the early flushing out of purin metabolites already discussed.

The purin base elimination does not appear to have been studied in older children.

Distribution of Sulphur in the Urine of Infants and Children.—Sulphur exists in foods in two forms: As salts of sulphuric acid and as organic sulphur, chiefly in the form of the amino-acid, cystin,



$$\begin{array}{l}\mathrm{S{-}CH_2{\cdot}CHNH_2{\cdot}COOH}\\ |\\ \mathrm{S{-}CH_2{\cdot}CHNH_2{\cdot}COOH}\end{array}$$

Since even the salts of sulphur are constant in different kinds of protein, it follows that the elimination of sulphur in the urine may be used as a measure of protein metabolism with nearly as much exactness as can the nitrogen. Taken by and large the total sulphur of the urine and the total nitrogen should therefore run parallel and this is a well attested fact.[276] With any given kind of food or in any given state of protein metabolism as in fasting, the ratio of N to S in the urine is fairly constant. Thus Cathcart[69] found in the case of a professional faster that the N:S ratio was 15:1. Since it is known that the N:S ratio in muscular tissue is 14 :1 it follows that muscular tissue must bear the brunt of the protein disintegration in fasting. When proteins are superimposed on otherwise adequate diets and the extra N. and S. eliminated in the urine are followed in short periods, it is usually found that the sulphur is excreted more rapidly than the nitrogen.

When it comes to the replacement of S lost from the body in fasting as compared with replacement of N, it is found that the sulphur seems to be retained easier, *i.e.*, in larger proportion relative to the intake, than is nitrogen. Furthermore, Lewis[267, 268] has brought to light the interesting fact that the administration of cystin under these conditions is more efficacious for retention of nitrogen than is the addition of an equivalent amount (N) of tryptophan or glycocoll. A more crucial comparison perhaps would have been serin or i-alanin with cystin. In any event the inference is that in covering a need for sulphur a coincident need for nitrogen is more easily met than if S were not in demand. A double use, in other words, is made of cystin, and this may be the key to its importance as a limiting factor in growth.[337]

Inorganic sulphates cannot supply the demand which is satisfied by cystin. Daniels and Rich[88] gave to different and parallel groups of rats diets which differed only as regards the presence or absence of inorganic sulphates in more than sufficient amount to cover the requirement for organic sulphur. When sufficient cystin was present (as casein) the two groups grew equally well, but when only 12 per cent. casein (an insufficient percentage to supply cystin) was given both groups failed to exactly the same degree. The sulphates could not be used to synthesize cystin.

The retention of sulphur is influenced by carbohydrate in exactly the same way as is the retention of N. This has not yet been studied as a separate problem in the infant; but in adults[470] and animals[434a] a larger "sparing" by carbohydrate than by fat is usually evident. Zeller, however, claims that when 20 per cent. of the non-nitrogenous calories are in the form of carbohydrate just as much sparing effect is obtained as when all are in this form and fat is entirely excluded. When 90 per cent. or more of the non-nitrogenous calories are in the form of fat body protein is broken down and the neutral sulphur, amino-acid and polypeptid nitrogen of the urine rise together.

The sulphur of the urine is present in three different forms: (1) inorganic sulphates; (2) ethereal or conjugated sulphates; and (3) neutral sulphur. The percentages of the total sulphur in which these fractions occur in the urines of adults on high and low protein foods have been given in Table 91 (p. 804). In infants on moderate amounts of protein, as in all cases where active retention of nitrogen is going on, the inorganic sulphates make up a smaller percentage of the total sulphur and the neutral sulphur especially, as a consequence rises.

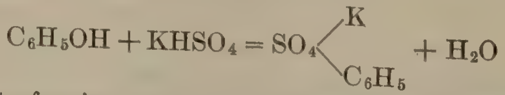
1. *Inorganic Sulphates.*—While preformed sulphates from the food make up a part of the sulphate sulphur found in the urine, the major part comes from the oxidation of organic sulphur tied up in the protein molecule. As an illustration of the influence of protein intake upon the distribution of sulphur in the urine of an infant the following table adapted from Talbot and Gamble may be presented.

Table 98.—Influence of Protein Intake on Distribution of the Sulphur in the Urine of an Infant (Talbot and Gamble)

Period	Age, months	Protein in food, grams	Nitrogen in urine, milligrams	Total SO_3, milligrams	Sulphur fractions					
					Inorganic SO_3		Ethereal SO_3		Neutral SO_3	
					Milligrams	Per cent.	Milligrams	Per cent.	Milligrams	Per cent.
1	5¼	10.2	959	190	111	58	28	15	51	27
2	5¾	20.0	1939	344	255	74	15	4	74	22
3	6	23.3	2494	428	363	85	13	3	52	12
4	6½	29.5	2688	465	387	83	15	3	63	14
5	6¾	36.2	3964	679	592	87	18	3	69	10

Although neither the total calories nor the distribution of the calories to carbohydrate and fat were perfectly constant, the variations were scarcely large enough to affect the partition of the sulphur. The only variable of significance, therefore, was the amount of protein (N and S) in the food. The rise in percentage of the inorganic sulphate and the consequent fall of the neutral sulphur fraction are very pronounced. The N retention in this experiment is given in Table 87 (p. 798). There is no relation between the retention and the inorganic sulphates for the reason that the nitrogen intake is so large in the later periods as to completely obscure the effect of retention. If the sulphur balance were known it is possible some reason for the peculiar behavior of the sulphates could be made out. As matters stand there is good agreement between the results on the infant and those reported by Folin for the adult. High protein means high inorganic sulphates both absolute and relative, and it means increased (absolute) excretion of neutral sulphur although this fraction makes up an even smaller percentage of the total.

2. *Ethereal Sulphates.*—The conjugation of phenol with sulphuric acid takes place according to this equation.



$$C_6H_5OH + KHSO_4 = SO_4\left\langle\begin{matrix} K \\ C_6H_5 \end{matrix}\right. + H_2O$$

The same sort of union may occur with any phenol derivative. This is a means of rendering toxic agents innocuous which is of great importance to the body. The conjugated or paired sulphates are now generally called the ethereal sulphates because of their structural resemblance to sulphuric ether.

While the ethereal sulphates have commonly been looked upon as a measure of putrefaction in the intestinal tract resulting in the liberation of phenols and related bodies, this cannot be their only significance for they are found in the urine of the newborn, albeit in very small quantity, and even in the amniotic fluid.[401] This probably means that the phenols in very small amount are formed in normal metabolism and are at once tied up with sulphate constantly being formed in the tissues by oxidation of organic sulphur. Senator found in the urine of newborns 2.21 mg. of ethereal sulphur per 100 c.c. as the average of six determinations. In older children naturally much larger absolute amounts are found and they make up a somewhat larger proportion of the total sulphur. In 29 determinations on 12 normal children Haldane reported the ratio of ethereal to inorganic sulphate at 1:18.8. This is about the same as shown in period 2 of Table 98. In most wasting diseases the proportion is higher; *e.g.*, in diphtheria 1:12.7. Often with cow's milk the percentage of ethereal sulphate sulphur is less than on breast milk.

Table 99.—Ethereal Sulphate and Neutral Sulphur in the Urine of Infants (Freund)

Child	Age, months	Weight	Food	Per cent. of total S	
				Neutral S	Ethereal S
K. L........	2½	4850	Mother's milk	46.6	6.6
K. L........	2¾	. . .	Two-third's cow's milk and milk sugar	31.9	2.0
M. W.......	4¼	5100	Mother's milk	51.5	6.0
P. K........	2	3920	Mother's milk	56.0	13.9

As Talbot and Gamble have pointed out the ammonia in the urine and still better in the feces (p. 751) is probably a more reliable measure of putrefaction in the infant than are the ethereal sulphates of the urine. The main reason for this is the fact that casein does not lend itself readily to the support of putrefaction. Moreover any protein can yield ammonia whereas only those containing much tyrosin, phenylalanin and the like can yield phenols.

The addition of phenols to the food will always produce an increase in the conjugated sulphates in the urine, and in cases of poisoning with carbolic acid the entire sulphur of the urine may take this form.

3. *Neutral Sulphur.*—The designation of neutral sulphur was given by Salkowski to cover all the unoxidized sulphur of the urine.

This consists mainly of hyposulphites, sulpho-cyanic acid or cyanates, derivatives of taurin, cystin, etc. They arise in part from the food but mainly from the endogenous proteolysis. Consequently as noted on p. 803 the neutral sulphur tends to remain constant under any given set of conditions.

This constancy in the absolute sense holds true for the infant no less than for the adult. The fairly high percentages seen (Tables 98 and 99) are due, as Tobler[428] has stated, more to the low total sulphur than to an absolutely high product of tissue katabolism. According to Eisner[111] the neutral sulphur of the infant's urine normally comes mainly from the resorbed bile although a part even in health he admits may have its origin in the proteinic acids. Pathologically as in starvation and conditions approaching starvation like marasmus the neutral sulphur represents true tissue disintegration. Schwarz[395] found 7.8 per cent. of the total sulphur present as neutral sulphur in the case of a 5½ year old normal boy and 7.4 per cent. for a rachitic child with normal musculature. In two other rachitics whose muscles were much wasted the percentage was 18 and 17 respectively.

Phosphorus as a Katabolite.—Phosphorus is present in food materials in four different forms: (1) phosphatids, *e.g.*, lecithin; (2) inorganic phosphates; (3) water soluble esters; and (4) phospho-proteins and nucleins.[194] There is no doubt that the growing organism can cover its requirements for this element if taken in the form of organic phosphorus, (1) or (4) of the above classification. This has been definitely proved both for lecithin and nucleo-proteins (casein). Evidence accumulates rapidly also that the inorganic phosphates are sufficient to maintain life in the mature animal and to support normal growth in the young. Fingerling[120] has proved that ducks maintained for long periods of time on phosphates as the sole source of phosphorus produced eggs just as rich in nucleins and lecithin as when fed on organic phosphorus. They also maintained body weight. McCollum as the result of long experience with rats and farm animals states that he has never seen growth enhanced by the addition of organic phosphorus to diets containing an adequate amount of inorganic phosphates.[276] Osborne and Mendel[339] state that in their experience with white rats "where protein furnished the phosphorus as in the case of casein, the inhibition of growth was not so pronounced as where the protein edestin, which contains no phosphorus, was furnished. With edestin foods, likewise, addition of inorganic phosphorus to the diet brought prompt responses, thus proving that aside from possible minute quantities, phosphorus in organic combination is not needed by the growing animal."

As already noted on page 776 phosphorus occurs normally also in the feces and may be increased by feeding calcium, carbonate or milk thus permitting the formation of insoluble phosphates. In children fed on mixed diets containing vegetable with a high calcium percentage the channel of excretion is largely through the feces. But this is not phosphorus of metabolism.

Phosphorus as a katabolite of protein whether of the food or of tissue is excreted mainly through the urine. In starvation the ratio of N to P_2O_5 is fairly constant, but is not quite so high as the ratio in meat which is 7.6:1. The lower ratio is due to the phosphorus which comes from the bones. In the famous observations of the Freunds[135] on the professional faster Succi the ratio was 5.7 on the first day, but it fell subsequently to 4.2 and 4.4. In Benedict's[33] observations upon his fasting man the ratio was 4.28 the first day, 5.26 on the eleventh, 4.96 on the twenty-first and 5.26 on the thirty-first.

In the newborn infants studied by Schloss and Crawford[385] the average P_2O_5 in the urine for four cases was 53.5, 6.4 and 10.8 mg. for three successive periods of three days each. In certain cases the amount was too small to be measured quantitatively and this confirms the previous findings of several observers quoted by Schloss and Crawford. Moll[308b] had emphasized the importance of an estimation of the urinary phosphorus. He found that the urine of a normally growing breast-fed infant contains from 10 to 20 mg. of P_2O_5 daily. In other words the urine is normally nearly phosphorus-free. Starvation did not materially increase the phosphorus excretion, from which it may be argued that the youthful tissues hold their phosphorus very tenaciously. In alimentary intoxications, however, the excretion of this element is greatly increased. In fact Moll infers that whenever an infant excretes considerable phosphorus, particularly if at the same time it is losing weight, it is sick.

Keller[227] who had previously reported the very scanty excretion of phosphorus in breast-fed infants also noted that a normal infant on a diet of cow's milk excretes considerably more of this element in the urine, the difference from the breast-fed infant being greater than could be accounted for by the greater phosphorus content of the ingested food. He inferred that the phosphorus of cow's milk, although absorbed equally well with that of mother's milk, is less well retained and turned to account by the tissues.

The relation of the organic phosphorus to the inorganic forms occurring in cow's milk as compared with breast milk to which Keller referred the difference in retention has been placed in doubt by later studies of the subject. Njegovan[327] in fact comes to the conclusion that the methods which have been used to determine the phosphatids are wholly unreliable and that milk does not contain any phosphatids. Czerny and Keller[86] after reviewing the latest investigations state that all theories which seek to explain the differences in phosphorus metabolism after feeding with mother's milk and cow's milk are valueless.

The retention of phosphorus is quite variable as is true of the other ash constituents. Schloss and Crawford give the following table for one of their newborn, breast-fed infants. These results are in close agreement with those of Michel who reported retention in two infants five days of age of 87.3 and 77.3 per cent. of the phosphorus (P_2O_5) ingested. Hoobler summarizes the retention in various cases reported

TABLE 100.—THE PHOSPHORUS BALANCE OF A NEWBORN INFANT DURING THREE DAY PERIODS (SCHLOSS AND CRAWFORD)

Period	P_2O_5 ingested, milligrams	P_2O_5 in urine and feces, milligrams	Balance, milligrams	Per cent. retention
1	155.5	85.5	+ 70.0	45.0
2	492.9	67.9	+425.0	86.2
3	483.0	88.8	+394.2	81.6

in the literature together with his own observations on a single infant nine months of age in the following table.

TABLE 101.—RETENTION OF PHOSPHORUS (P_2O_5) IN INFANCY (HOOBLER)

Food	Intake	Elimination		Retention	
		Feces	Urine	Grams	Per cent.
Mother's milk	0.2768	0.0363	0.0481	0.192	69.13
Mother's milk, 5 months	0.2030	0.0220	0.088	0.093	45.9
Cow's milk	1.4429	0.5352	0.5003	0.4074	30.7
Cow's milk (Keller's 2¾ mo.)	0.8248	0.1073	0.4106	0.3068	37.2
Cow's milk (Blauberg's 7½ mo.)	2.0605	0.9627	0.5899	0.5079	24.2
Diluted cow's milk, 2.1 per cent. fat (Hoobler)	2.2155	0.7648	1.152	0.3320	14.5
Cow's milk, whole, 4 per cent. fat (Hoobler)	2.7418	0.59914	2.009	0.1336	4.8
Cow's milk and cream, 5.4 per cent. fat	2.2346	0.3789	1.336	0.6196	27.7

Hoobler states that the daily needs of the infant for phosphorus is satisfied by a daily intake of 0.7 to 0.8 gm. of P_2O_5 as a minimum and 1 to 2 gm. as a maximum, the wide variation being due to the close association of this element with the protein molecule and therefore to the fate of protein in metabolism. Koeppe[236] who studied the excretion in two normal bottle-fed infants over long periods of time, the diet being varied by feeding with "butter-milk soup," cow's milk diluted one-half, cow's milk diluted to two-thirds strength, whole cow's milk, oatmeal water and cow's milk containing an addition of 1 gm. of NaCl, drew the following conclusions, "(1) on equal quantities of food the amount of P_2O_5 excreted in the urine varies with the kind of food, (2) on the same kind of food the amount excreted is conditioned by the amount of food."[232]

Other Ash Constituents.—The metabolism beyond the alimentary wall of other ash constituents than those immediately associated with the metabolism of protein will be summarized briefly in several tables taken from the most recent studies of this subject. These studies have been referred to quite extensively under the heading of the utilization of ash constituents.

For the breast-fed infant the researches of Tobler and Noll[430] and of Lindberg[269] may be cited. In both periods shown in the table Lindberg

TABLE 102.—MINERAL METABOLISM OF A BREAST-FED INFANT TWO AND ONE-HALF MONTHS (TOBLER AND NOLL)

Element	Intake	Output			Retention	
		Feces	Urine	Total	Balance	Per cent.
Nitrogen..........	1.146	0.132	0.464	0.596	0.550	48.9
Total ash..........	1.142	0.399	0.491	0.890	0.252	22.1
K_2O..............	0.343	0.058	0.112	0.171	0.173	50.3
Na_2O.............	0.221	0.008	0.008	0.016	0.205	92.6
CaO..............	0.239	0.148	0.037	0.185	0.053	22.3
M_9O..............	0.028	......	0.018			
Cl_2...............	0.069	0.003	0.056	0.059	0.011	15.3
SO_3..............	0.137	0.036	0.044	0.08	0.056	41.3
P_2O_5.............	0.210	0.034	0.057	0.091	0.119	56.5

TABLE 103.—MINERAL METABOLISM OF A TWO AND ONE-HALF MONTHS BREAST-FED INFANT IN TWO THREE-DAY PERIODS (LINDBERG)

Ash constituents	Intake	Output			Retention	
		Urine	Feces	Total	Grams	Per cent. of intake
Total ash...... I	1.4788	0.5268	0.5285	1.0553	0.4235	28.64
II	1.4714	0.4348	0.5824	1.0171	0.4543	30.87
K_2O........... I	0.4234	0.2671	0.0819	0.3490	0.0744	17.57
II	0.4421	0.2114	0.1078	0.3192	0.1229	27.80
Na_2O.......... I	0.1308	0.0165	0.0316	0.0480	0.0828	63.28
II	0.1618	0.0420	0.0460	0.0880	0.0738	45.59
CaO........... I	0.2572	0.0183	0.1827	0.2010	0.0562	21.86
II	0.2615	0.0228	0.1748	0.1976	0.0639	24.43
MgO.......... I	0.0501	0.0160	0.0152	0.0312	0.0189	37.68
II	0.0484	0.0106	0.0238	0.0344	0.0140	28.86
NaCl.......... I	0.4189	0.2515	0.0214	0.2729	0.1460	34.86
II	0.4208	0.2342	0.0402	0.2744	0.1464	34.79
P_2O_5.......... I	0.2940	0.0464	0.0554	0.1018	0.1922	65.39
II	0.2889	0.0875	0.0618	0.1439	0.1397	48.34

fed his subject on expressed breast-milk containing in 1,000 parts 1.715 to 1.729 gm. Nitrogen, 36.6–44.0 gm. fat, 2.037–2.012 gm. ash, 0.4 gm. P_2O_5, 0.57–0.58 gm. NaCl, 0.35–0.362 gm. CaO, 0.0667–

0.067 gm. MgO, 0.576–0.612 gm. K_2O, 0.178–0.224 gm. Na_2O. The object of this experiment was to determine the influence of the fat of breast-milk upon the utilization and retention of the ash constituents. The influence upon utilization has been shown in the several tables 75, 77, and 79, where Lindberg's results are presented together with those of other observers.

In a second experiment, not shown in the table, the fat was increased to 5.7 to 6.6 per cent. The greatest effect as regards retention was upon the calcium and phosphorus. Only 0.038 gm. CaO was retained daily in the first half as against 0.056 and 0.0639 gm. in the previous experiment (Table 103) and in the second half there was an actual net loss of 0.033 gm. The phosphorus elimination through the urine was considerably increased but this is not accounted for by the formation of soaps. Lindberg believes the influence of fat upon the mineral metabolism is to be sought in the intermediary metabolism (p. 774).

In this connection it is interesting to compute the amounts of the several ash constituents necessary to the formation of a unit of growth in weight. Such a computation has been made by several observers. The following table prepared by Mattill and Mattill[283b] is presented through the courtesy of these writers. Lindberg points out that the practice of calculating gain in mineral constituents upon the basis of the composition of the newborn, as Camerer and Solder have done, is not exact; for it cannot be assumed that the composition of the body of an older infant is the same as in the newborn. The nitrogen content of the muscles of the infant is much less than that of the adult. The Ca content decreases with age, likewise the sodium; while contrariwise the potassium and phosphoric acid increase.

TABLE 104.—AMOUNTS OF MINERAL SUBSTANCES NECESSARY TO THE FORMATION OF 100 GM. BODY WEIGHT (MATTILL AND MATTILL)

Author	Age of infant, months	K_2O, grams	Na_2O, grams	CaO, grams	MgO, grams	P_2O_5, grams
Camerer and Soldner (based on composition of newborn body)	....	0.20	0.24	1.00	0.04	1.04
Crohnheim and Müller (based on retention).	3 to 4	1.53	0.66	1.97	0.18	1.77
	5 to 6	1.26	0.49	0.48	0.12	0.78
Meyer, L. F. (based on fasting)	....	0.73	0.17	0.3	....	1.17
Tobler and Noll (based on average gain per day of 24.3 gm.)	2½	0.69	0.82	0.21	....	0.47

For older children the retention of ash constituents has been studied by Jundelt[218a] and Herbst.[183] The former made observations on two boys five and one-half and seven and three-quarter years of age, who were admitted to the hospital suffering with light attacks of polyarthritis, but at the time of the metabolism study were free of symptoms. The two boys designated as K and N received the following food calculated per kilogram of body weight.

Kilogram of body weight	Protein, grams	Fat, grams	CH, grams	Calories
K—5½ years, weight 18.4 kg.	2.899	2.686	10.792	81.1
N—7¾ years, weight 23.1 kg.	2.915	2.697	10.893	81.9

TABLE 105.—MINERAL METABOLISM OF TWO BOYS FIVE AND ONE-HALF AND SEVEN AND THREE-QUARTER YEARS OF AGE (JUNDELT)

Ash constituents	Intake		Output				Retention	
			Feces		Urine			
	K	*N*	*K*	*N*	*K*	*N*	*K*	*N*
Total ash	0.7471	0.6969	0.1336	0.1242	0.4691	0.4288	+0.1444	+0.1439
P_2O_5	0.1443	0.1363	0.0491	0.0431	0.0638	0.0635	+0.0315	+0.0297
CaO	0.0596	0.0757	0.0498	0.0416	0.0069	0.0048	+0.0029	+0.0294
MgO	0.0707	0.0648	0.0471	0.0411	0.0097	0.0079	+0.0140	+0.0159
K_2O	0.1411	0.1363	0.0125	0.0127	0.1162	0.1059	+0.0124	+0.0177
Na_2O	0.3455	0.2239	0.0108	0.0117	0.1039	0.1027	+0.2307	+0.1095
Cl (NaCl)	0.3439	0.3237	0.0025	0.0038	0.3091	0.2922	+0.0323	+0.0277

Herbst's studies were made upon two normal boys 13 years, 10 months and 14 years, 7 months of age, while on a hike, and during a subsequent resting period. The results in brief are given below.

TABLE 106.—DAILY RETENTION OF CaO, P_2O_5 AND N, PER KILOGRAM OF BODY WEIGHT OF TWO NORMAL BOYS (HERBST)

	CaO retained, grams	P_2O_5 retained, grams	N retained, grams
Subject I (13 yr. 10 mo.)	0.0075	0.0148	+0.013 (6 days work)
	0.0042	0.0138	+0.045 (6 days rest)
Subject II (14 yr. 7 mo.)	0.0118	0.0039	−0.020 (6 days work)
	0.0093	0.0111	+0.029 (6 days rest)

These several studies constitute a beginning, but only a beginning, toward the attainment of a proper conception of the mineral needs of the growing child. Osborne and Mendel have recently drawn attention to the paucity of information regarding the part played by the several inorganic elements of the diet. They say, "it is obvious that a growing and bone-producing, or a milk-producing animal requires calcium and phosphoric acid, and that at all periods of life chlorides are essential for the production of gastric juice. Conclusions like these afford an insufficient basis regarding the *specific* use of these as of the other elements." They then outline a method for study of the importance for growth in rats of the several elements by exclusion of them one after the other from the diet. This method obviously is not practicable with infants but the information gained from animal experiment may be checked and controlled by careful observation on children. It is highly important that such observations on a large scale in a carefully controlled institution should be inaugurated at an early date. They should be coupled with observations upon the physiology of vitamines, for there is nothing more certain than that the mineral metabolism must be profoundly affected by these accessory substances. The chapter which should logically follow this one can be written only when such an extensive study has been completed.

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CHAPTER VI

APPLICATION OF PHYSICAL CHEMISTRY TO THE PHYSIOLOGY OF CHILDHOOD*

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Definitions.—Physical Chemistry (of solutions) is the study of chemical substances through changes in the physical properties of their solutions, and deals especially with energy relations.

Aqueous Solutions.—When a substance dissolves in water it becomes more or less dispersed through the solution. If the dispersion is very great we have a true solution and if the dispersion is not so great, we have a colloid solution. But there is no sharp distinction between the two. Molecules of protein are so large that no great dispersion is possible without breaking down molecules; hence, the solution is always colloidal. Other substances may exist in true solution or in colloid solution and are then said to exist either in the crystalloid or colloid state of dispersion. There are a number of distinctive properties of these two states of matter which are used to separate them, but any one property can not be used as a criterion.

True dissolved substances may affect the color of light or rotate the plane of polarized light or even disperse (scatter) the light to a slight degree. Colloid solutions disperse light and at the same time polarize it and change its color (Tyndall phenomenon).

Matter in the colloid state does not diffuse easily through membranes and does not crystallize readily.

Colloid solutions may gel or set to form gels (jellies). The state of being in colloid solution or in gel is called the colloid state of aggregation.

Substances which may exist either in true or colloid solutions form suspension colloids (suspensoids) and those which exist only as colloids are called emulsion colloids (emulsoids), but there is no sharp line of distinction between the two groups.

Emulsoids have large molecular weights and great affinities for water and greatly increase the viscosity of water. They are the only colloids found in the animal body. From them, colloids took their name (glue-like substances). Familiar examples are glue, which is an impure gelatin and agar-agar which is a carbohydrate.

The following properties of solutions are often determined in physicochemical studies. (In all these measurements, since only aqueous solutions are considered in physiology, distilled water is taken as the standard. A standard temperature must be used except in the case of freezing points. Temperature is always measured on the Centigrade scale (Celsius) and weights and measures in the metric system).

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* Owing to lack of space and the fact that some sections are treated in other parts of this work, a full discussion of this subject is not attempted.

Density.—The density of a solution is the weight of a known volume of it as compared with the weight of the same volume of water at four degrees. For convenience, however, other temperatures have been used. The density of a solution decreases with rise of temperature and its volume increases. Thus, if we take a liter of water at four degrees, at which temperature it weighs 1 kg., it is more than a liter at any higher temperature. The liter flask expands slightly but the solution expands more readily as the temperature is raised. The density of a solution is proportional to the concentration of the dissolved substances. The density of blood serum is about 1.03, of blood 1.06 and of cerebrospinal fluid less than 1.01.

Refractive Index.—The refractive index of a solution is proportional to the concentration of the dissolved substances. The addition of 1 per cent. of protein raises the refractive index of an aqueous solution 0.001 per cent. The refractive index of serum is 1.345 to 1.35.

Viscosity.—The viscosity of an emulsoid solution is proportional to the concentration of the emulsoid. The viscosity decreases with rise in temperature. The greater the hydration of the colloid, the greater the viscosity. For this reason the addition of small amounts of acid to colloid solutions may increase the viscosity. In studying the viscosity of the blood, two factors must be considered, the viscosity of the plasma and the cell-count. The viscosity is measured by the time required for the passage of a given quantity of solution through a capillary tube propelled by gravity or at a certain definite pressure. If the tube is so small that it is plugged by the blood cells, the time required by the flow of the blood is greatly increased. This is the condition in the capillaries and therefore the effective viscosity of the blood in the body cannot be measured except by perfusion through capillaries. As usually measured, the viscosity of normal blood is about four to six (as compared with H_2O).

Polarized Light and Rotation of the Plane of Polarized Light.—Crystals polarize light and are then called double refractive or anisotropic. Colloid solutions may disperse light. This is especially noticeable in a powerful dark field illumination such as used in the ultramicroscope. The light dispersed is polarized and may be changed in color. Colloids will polarize light when put under tension (forcibly deformed). A piece of catgut is made anisotropic by stretching and if dried in this condition, remains so unless it is allowed to absorb the lost water in a relaxed condition.

When asymmetric molecules in solution rotate the plane of polarized light, the rotation is proportional to the concentration of molecules. In this way the concentration of sugar solutions is measured in the polarimeter.

Surface Tension and Adsorption.—The surface film of a liquid is under tension. It is as though the fluid were inclosed in a thin rubber bag composed of the stretched surface film, except that whenever this film is forcibly broken, immediately it forms anew over the exposed surface. If the fluid is allowed to drop from a pipette the weight of a drop is proportional to the surface tension. A pipette used for measurement of surface tension has a capillary tube inserted in the out-flow to retard the rate of flow and has a carefully ground-off dropping surface about 5 mm. in diameter. This pipette may be fitted to a weighing bottle so that little evaporation occurs before weighing (drop-weight method). It is used in testing the meiostagmin reaction (Morgan, 1913). Adsorption is the concentration of a dissolved substance in the surface layer of a solution and substances which lower the surface tension are easily adsorbed. The surface tension of blood or serum varies with temperature and is said to be about 0.89 at room temperature. This value should be multiplied by about 72 to reduce to dynes per centimeter. Morgan obtained 45.4 dynes cm. at 37°, but this is too low.

Electric Conductivity.—When a salt or acid or base is dissolved in water, it disperses into separate molecules and some of these molecules split into ions. An ion is a small particle bearing one or more positive or negative charges of electricity. The greater the dilution of the solution, the greater the proportion of molecules that are ionized. Water itself ionizes to a very small extent. The percentage of the molecules that are ionized is 0.000,000,2 per cent. This is so small as to be practically negligible and the ions in an aqueous solution may be said to be only those of dissolved substances. The unionized molecules of water or the dissolved substances are electric insulators but the ions in their movement in the solution carry the electric charges, therefore, the ionization can be measured by determining the electric conductivity of the solution. Electric conductivity is the reciprocal of the resistance in ohms. The electric conductivity of blood serum is about 0.01 reciprocal ohms at 15 degrees and increases about 2 per cent. per degree. The corpuscles are electric insulators and lower the conductivity of blood; hence, the cell-count may be calculated from the electric conductivity (Stewart).

Diffusion.—When two unlike solutions are in contact with the two sides of a porous partition or membrane, diffusion takes place through the membrane until the two solutions are similar. The molecules that pass through the membrane more easily, diffuse more readily than those having difficulty in getting through the membrane. Water passes through wet animal membranes like pig's bladder more easily than most dissolved substances; hence, the diffusion is chiefly confined to the water molecules. It is useful, however, to confine the term diffusion to the passage of dissolved substances through the membrane and use the word, osmosis, for the passage of water.

Osmotic Pressure and Freezing Point.—Some membranes have been found which entirely prohibit the passage of certain dissolved substances, such as sugars. Such membranes are composed of colloids with a very low water content and are called semipermeable membranes and allow water only to pass. If two unlike solutions are placed on two sides of such a membrane, osmosis of water takes place from the side in which the water is the most concentrated to the side in which it is least concentrated, so as to equalize the solutions. That is to say that water passes toward the side in which the dissolved substance is most concentrated. The passage of this water may give rise to a pressure called osmotic pressure. Thus if the membrane containing the more concentrated solution is made into the form of a bag connected with a manometer, the passage of water in the bag will cause a pressure which may be measured on the manometer. Since osmotic pressures are usually very great, it is difficult to get bags that will withstand them but it is found that the osmotic pressure of a solution may be calculated from its freezing point. If we subtract its freezing point from the freezing point of pure water and multiply this difference by twelve, we obtain osmotic pressure in atmospheres at 0°. The osmotic pressure rises slightly with temperature. The osmotic pressure of blood at body temperature is about eight atmospheres, its freezing point being −0.58°C.

THERMODYNAMICS OR CALORIMETRY

It follows from the first law of thermodynamics that each quantity of energy, whether potential or kinetic, can be measured in a common unit by transforming it into heat and measuring the heat. Heat is taken as the standard since all other forms of energy may be easily transformed into heat whereas practical difficulties arise in the transformation of heat into other forms of energy (from the second law of thermodynamics). Most chemical reactions that take place easily liberate energy. If allowed to proceed unguided this energy may be entirely transformed into heat. Under certain conditions, however, at least part of this energy may be compelled to do work. The maximum amount of the energy that can be transformed into work under the most favorable conditions is called the "free energy" of the reaction. The usual method of measuring the free energy of a chemical reaction is the conversion of it into electrical energy, and measurement of the electrical energy. This method is used in Physiology in the determination of hydrogen ion concentration. The free energy of the following reaction:

$$2H^+ = H_2 + 2 \text{ electrons}$$

is converted into electrical energy and measured with the potentiometer. Knowing the energy derived from the reaction at unit concentration and studying the energy at unknown concentration the value of this unknown may be calculated.

The unit of heat energy is the calorie. The small or gram *calorie* is the heat required to raise the temperature of 1 gm. of water 1 degree, and the large or kilogram *Calorie* is the heat required to raise a kilogram of water 1 degree. In Physiology the large Calorie is used exclusively.

The energy of the human body is derived from the potential energy of carbohydrates, fats and proteins. Some of free energy appears as work and the remainder of the potential energy liberated by the combustion of food is useful in maintaining the temperature of the body, just as the exhaust steam of a locomotive is used in warming the cars. By transforming the work into heat the total energy may be measured as heat. The apparatus for such measurements is called a calorimeter. Calorimeters in which a man may live and work for a month have been constructed. Calorimeters for the burning of food directly are called bomb calorimeters.

It is found that the heat produced by the burning of 1 gm. of carbohydrate or fat is the same whether it is burned in the human body or in the bomb calorimeter, but the heat produced by the burning of 1 gm. of protein is greater in the bomb calorimeter than in the body due to the fact that it is incompletely burned in the body. The extent to which protein is burned is very variable as the waste products may be eliminated as CO_2 and urea or CO_2 and NH_3, etc. In the bomb calorimeter the burning of 1 gm. glucose yields 3.74 Calories, 1 gm. milk sugar 3.95 Calories., 1 gm. starch 4.19 Calories, 1 gm. butter fat 9.23 Calories, and 1 gm. casein 5.86 Calorie. In the body the burning of 1 gm. protein usually produces less than 4.5 Calories of heat and 4.1 Calories per gram of ingested protein is considered normal.

Benedict and Talbot have studied the calorimetry of infants during the first week. The stored glycogen at birth lasts about 24 hours or less. Mothers milk during the first week is insufficient for maintenance, even though no growth takes place. They suppose that acidosis due to lack of carbohydrate is likely to occur unless sufficient glucose is fed so that the infant does not use its body fat. The basal metabolism is 44 Calories per kg. To this must be added four Calories lost in feces and 14 Calories for exercise, making a total of 62 Calories per kg. The metabolism of the infant increases after birth to about 60 Calories per kg. (Murlin and Hoobler). Apparently the metabolism is influenced by heat loss (surface area, clothing, humidity and temperature of the air) to a greater extent than by weight. According to Lissauer the surface area of newborn $= 10.3 \sqrt[3]{\text{weight}^2}$ (Surface Law).

HYDROGEN ION CONCENTRATION

The concentration of different chemical substances is usually a problem of quantitative analysis but when such substances exist only in solution and never in a dry state, the methods of physical chemistry are necessary for its determination. Since the molecular weight of water is 18 and there are 1000 gm. to the liter the molecular concentration of water is 52 gm. molecules to the liter. Practically all of this exists in the non-dissociated condition. Only 1 part in 520,000,000 is dissociated. This dissociation is expressed by the equation $H_2O =$

$H^+ + OH^-$. Since there are the same number of hydrogen ions (H^+) as hydroxyl ions (OH^-) the concentration of each of these is 1 gm. atom in 10,000,000 liters, or as it usually expressed to 10^{-7} N. From the law of mass action, we obtain the following equation: $H^+ \times OH^- = 10^{-14}$. That is to say if we increase hydrogen ions, some of them will combine with hydroxyl ions and form water and thus reduce the concentration of the hydroxyl ions and *vice versa* so that the product of the concentration of the hydrogen ions multiplied by concentration of hydroxyl ions is always equal to 10^{-14}, therefore, if we add an acid such as HCl which dissociates into H^+ and Cl^- we thus increase the hydrogen ions and decrease the hydroxyl ions or if we add an alkali such as KOH which dissociates into K^+ and OH^- we increase the concentration of hydroxyl ions and decrease the concentration of hydrogen ions. Since the concentration of hydrogen ions in water is 10^{-7} and water is a neutral fluid, any solution is neutral when the concentration of hydrogen ions is 10^{-7} and is acid when the concentration of the hydrogen ions is greater, and alkaline when less. Therefore in any solution no matter how numerous are the dissolved substances, the true acidity or alkalinity is measured by the concentration of hydrogen ions (or hydroxyl ions). Since the hydrogen ions are easier to measure they are more commonly chosen. The principle involved in their determination is the measurement of the free energy in the reaction: $H_2 = 2H^+ + 2$ electrons. Since the method and the mathematics involved are very complicated, it will not be described here. There is, however, an indirect method which when standardized by the above method gives workable results, and that is the method of indicators (dyes). Indicators are weak acids or bases of decided colors. Those which we will use mostly are weak acids and dissociate according to the following formula: H color = H^+ + color. Now it so happens that the combination of the hydrogen ion with the color radical changes the color and can be detected with the eye. If we add another acid to a color-acid the concentration of hydrogen ions is increased. But the color acid can not only dissociate hydrogen ions but can also combine with them. The additional hydrogen ions tend to combine with free color radicals to form (H color) and in this way a change may be detected with the eye. If an alkali is added there is an increase in hydroxyl ions and these combine with some of the hydrogen ions given off by the color acid and more of the color acid dissociates so as to replenish the hydrogen ions and the color of the solution is changed. The numerical relations are deduced from the Law of Mass Action. It is not necessary to know the formulæ since all that is necessary is to know that a change in the concentration of the hydrogen ions changes the color of the solution. The color is also changed by certain dissolved substances and hence the method has to be standardized each time there is any very great change in these dissolved substances. Neutral salts interfere with the indicator method to a slight degree but proteins interfere to a very marked degree. It is, in fact, impossible to use the indicator method in a solution with as high protein content as blood plasma, if very fine results are desired. Indicators have been used, however, for the stomach contents but in this case a comparatively rough measurement is sufficient. For all biological work there is liable to be some protein present and hence indicators have been selected which are least affected by proteins.

Since the hydrogen ion concentration is so small, methods have been devised of making the writing-down of the quantity easy. For instance, the hydrogen ion concentration of water is 0.0000001 N, but this is usually expressed as 10^{-7}. Even this shortened expression becomes difficult on the typewriter and therefore Sörensen decided to drop the 10 and the minus sign and use merely the 7. This number is the logarithm of the hydrogen ion concentration with the sign changed, in other words, it is the minus logarithm ($-\log. H^+$). Since it is desirable to abbreviate the term *minus logarithm*, Sörensen, writing in German and calling it "die Potenz der H^+" abbreviated it "pH." In other words, water is pH $= 7$, in acid solution pH is less than 7, and in alkaline solution pH is greater than 7. Since HCl is nearly completely dissociated in dilute solution we can express the hydrogen ions concentration thus:

HCl concentration	H^+ concentration	pH
0.1 (approx.)	0.1 N	1
0.01 N	0.01 N	2
0.001 N	0.001 N	3
0.0001 N	0.0001 N	4
Boiled distilled water	....	7

and since KOH is nearly completely dissociated in dilute solution, 0.01 N KOH is pH 12 (approx.).

Every indicator shows a maximum color change on each side of a definite pH which differs for each indicator. In the following table some useful indicators are given and the pH at which they change:

Methyl violet	pH 1 to 3
Tetrabromphenolsulfonephthalein	pH 4
Methyl red	pH 5
Dibromorthocresolsulfonephthalein	pH 6
Phenolsulfonephthalein	pH 7
Orthocresolsulfonephthalein	pH 8
Thymolsulfonephthalein	pH 9

In using the indicator method it is convenient to have standard solutions whose hydrogen ion concentration is not easily changed by the alkali of glass vessels or small amounts of CO_2 leaking in through the stopper. Most of the standard solutions that have been proposed contain organic substances which are attacked by mould or bacteria. It is, however, possible to make a whole set of standard solutions of phosphates and borates which are very stable.

Hydrogen Ion Concentration of the Alimentary Tract.—It is commonly believed that digestion takes place only in distinctly acid or alkaline media. That is to say, that salivary and intestinal digestion go on only in alkaline media and gastric digestion only in acid media. This idea must be modified. In the first place there are two functions of the particular reaction. First, the effect of reaction on the enzyme and on the food to be digested (substrate). For instance, acid is necessary to change pepsinogen into pepsin which is distinctly an effect on the enzyme. On the other hand, acid in the stomach causes swelling and the softening of the proteins to be digested and it is claimed by Bradley and others that this swelling increases the rate of digestion. It was shown by Sörensen and his followers that a different hydrogen ion concentration worked best for the action of pepsin on albumin from that which was best for the action of pepsin on gelatin. Now since the enzyme was the same in these two cases but the protein was different, it seems evident that the effect of the hydrogen ions is on the protein and not on the enzyme. In some cases, however, hydrogen ions take the place of enzymes, for instance, in the splitting of cane sugar into dextrose and levulose in an acid solution.

In the second place it has been found that although high acidities may occur in the stomach, very distinct alkalinities do not occur in the alimentary tract. If we titrate the intestinal contents, considerable acid is used in the breaking-up of the bicarbonates. In this way the CO_2 is displaced by the acid used in titration, but if we measure the hydrogen ion concentration of the intestinal contents we find that it is very close to neutrality but on the acid side.

The reaction of the contents of infant's alimentary tract is given in the following table:

Fresh milk	pH 7.0
Saliva	pH 6.9
Gastric juice	pH 2.3
Stomach contents	pH 5.3
Duodenal contents	pH 3.1
Ileum contents	pH 6.3 (Pups)

This last determination could not be made on an infant and was made on pups. The longer the ileum in proportion to body the less the acidity seems to be. The slight acidity of the ileum is partly due to CO_2 (liberated by HCl from pancreatic juice), acid-albuminates and amino-acids. Lactic acid may play a part since the hydrogen ion concentration of rabbit's ileum is greater on carrot diet in which sugar may form lactic acid, than on oats.

Both pepsin and trypsin are found in the duodenal contents of the infant and it is possible that both of them aid in the splitting of proteins in the intestine. The reaction is sufficiently acid for the action of pepsin in the pylorus and duodenum. Perhaps trypsin more easily attacks proteins that have been swollen by the acid of the stomach. Hydrogen ions cause the splitting of cane and milk sugar. Huenekens found a partial adaptation of the pH of the stomach of children to a precocious feeding of meat.

Hydrogen Ion Concentration of the Blood and Other Body Fluids.—It was shown by a number of workers that the respiratory center is affected by the hydrogen ion concentration of the blood. The question whether CO_2 can be substituted by any other acid can not be settled since there are always carbonates in the respiratory center itself (even though they are washed out of the blood vessels) and CO_2 is liberated from them by other acids. It is true, however, that through this action of the respiratory center, the hydrogen ion concentration of the blood is maintained so remarkably constant that changes in it are more difficult to determine than changes in the osmotic pressure or temperature. The pH of the blood is about 7.45 but has been said to vary from about 7.4 to about 7.5. It varies slightly in the same individual due to changed activity of the respiratory center as, for instance, due to the effect of drugs. It also is slightly different in one individual from that in another and in one species from that in another, but at present these slight differences can only be detected by the most careful technic and the differences found in the literature are vitiated by technical errors.

The hydrogen ion concentration of the blood depends on two factors. First, the concentration of bicarbonates, and second, the partial pressure of CO_2. The blood is brought into such intimate contact with the air in the lungs, that the partial pressure of CO_2 in the arterial blood is practically the same as that in the alveolar air in the lungs, therefore, if we measure the CO_2 of the alveolar air we have a sufficiently accurate estimation of the CO_2 pressure of the blood. The infant's lung is so small that it is difficult to collect the alveolar air by Haldane's method but if the infant is allowed to rebreathe the air in a 100 c.c. rubber bag, 30 seconds, and the air in this bag analyzed, a good index of the CO_2 pressure of the blood is obtained. The bicarbonate of the blood is unequally distributed between corpuscles and plasma and the ratio changes with the CO_2 content. If CO_2 is introduced into the blood, bicarbonates pass from the corpuscles into the plasma but if the blood is exposed to air so that CO_2 escapes, bicarbonates pass from the plasma into the corpuscles. It is impossible to titrate the bicarbonates of undiluted blood or plasma with an indicator, owing to the large amount of protein. Van Slyke, Stillman and Cullen dilute the plasma 12 times with H_2O. It is necessary in any method to collect and centrifuge the blood without exposure to air and make determinations on the oxalated plasma. The bicarbonates in the plasma may be titrated using a rotating hydrogen electrode (McClendon, Meysenberg, Engstrand and King) or they may be estimated by the gasometric method of Van Slyke or titrated after dilution, McClendon, Cole, Engstrand and Middlekauft. The bicarbonate content of the cerebrospinal fluid is 10 per cent. lower than that of the blood and may be titrated with HCl using dibromorthocresolsulfonephthalein as indicator (McClendon, 1918) and therefore, this method may be used to estimate the bicarbonate content of the blood. The hydrogen ion concentration of the blood may be determined from the following figure (Fig. 245) if the bicarbonate content and CO_2 pressure are known.

It has been shown that if for any cause there is a decrease of metabolism of carbohydrates, either due to starvation or diabetes, that abnormal acids are produced from the metabolism of fats and appear in the blood, thus decomposing the bicarbonates, and are excreted as sodium salts. In this way, the sodium of the bicarbonates is depleted. Great reduction of bicarbonates in itself is injurious in animal experiments. It is probably necessary to have sodium for the elimination of the abnormal acids. The bicarbonates in the blood act as buffers, thus preserving the hydrogen ion concentration. It has been found that the hydrogen ion concentration is remarkably constant during life even though the bicarbonates are very much depleted. It is conceivable, however, that depletion of the bicarbonates in the blood will cause a depletion in the whole body and that dangerous changes

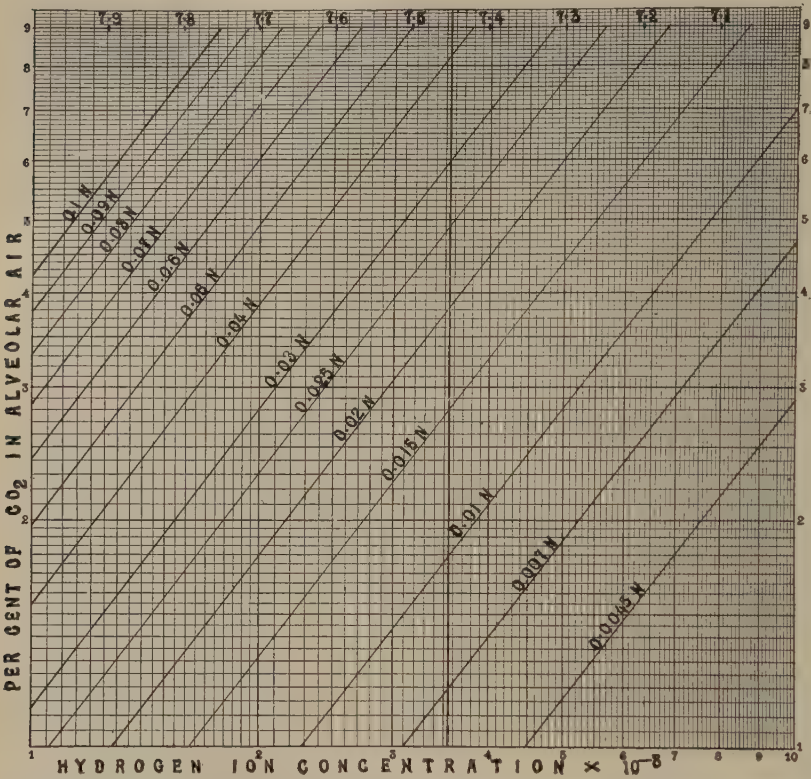

FIG. 245.—To determine the H^+ concentration of blood in the body, first determine CO_2 in alveolar air then titrate bicarbonate in diluted blood plasma. Find value for CO_2 in table, follow horizontal line until it cuts diagonal corresponding to titration value of bicarbonate. The vertical line at this intersection marks the H^+ concentration at the bottom, and pH at the top of the chart.

in hydrogen ion concentration may take place in some of the cells and be the real cause of death.

Acidosis is now understood as a depletion of the bicarbonates of the blood. It is impracticable if not impossible to determine acidosis by measuring hydrogen ion concentration of the blood, as no significant change has ever been shown by a reliable method and careful technic. Acidosis may be detected either by a determination of the bicarbonates of the blood or by determination of the alveolar CO_2, though the former is more reliable, the latter may sometimes be more convenient as a sample of blood (or spinal fluid) is not necessary.

According to Higgins and also Ylppö children are especially liable to acidosis and perhaps are always in a state of acidosis when compared with adults. Seham has recently found, however, that this statement must be made with caution and that technical errors arise from using too large a bag for rebreathing air before taking a sample.

Alkali is excreted, not only by the kidney but by the bowel and Howland and Marriott have shown that acidosis occurs in a certain form of diarrhea in children.

Acidosis is also present with starvation and cyclic vomiting, as well as in several diseases not confined to childhood.

It has often been found empirically that alkali therapy is beneficial. The study of the pH of the alimentary tract suggests that the alkali may be beneficial in the blood but detrimental to digestion. At any rate it seems illogical to introduce alkali into the full stomach unless it is desired to open the pylorus in cases of delayed evacuation of the stomach. The alkali should be in the form of sodium bicarbonate, since Mg and Ca are not readily absorbed and may even be excreted by the bowel. Sodium salts of organic acids that are readily oxidized may be converted into sodium bicarbonate in the body.

Hydrogen ion concentration is important in the preservation of vitamins in infants' food (McClendon and Sharp). The acidity of tomatoes and fruits protects the antiscorbutic vitamin against heat and desiccation used in preservation.

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CHAPTER VII

HYGIENE OF THE HOME

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Fresh Air. Ventilation.—That every home in which people live should have a maximum of fresh air, that is, air without ingredients which are harmful, goes without saying.

Moisture of Air.—When we say that the air in a house is fresh, we mean that the air within the house has the same composition as the air without. The composition of the air in any given locality will vary somewhat, depending upon the altitude, the character of the soil, the foliage, the proximity to bodies of water, the rainfall, the character of the industries, etc. The words "Fresh Air" therefore, as commonly used, are only relative.

The atmospheric air is usually described as consisting of a mixture of three gases, nitrogen, oxygen and carbon dioxide. The nitrogen and oxygen are supposed to maintain fairly definite percentages, the carbon dioxide being very variable. To these should be added a fourth, water vapor, which, as will later be shown, is most variable of all.

In manufacturing communities, where great volumes of smoke consisting of various gases is permitted to escape into the air, naturally admixture of these gases will vary much depending upon the wind, the barometric pressure and other factors.

We will assume that a given house is located in an ideal community where the air has a minimum of deleterious ingredients. This house is located in Northern Minnesota where during three summer months the weather is either moderately warm or extremely warm, in the spring and fall it is moderately cool, and in the winter for several months it is moderately cold and sometimes as low as 20°F. below zero.

During the warm summer months when the windows can be kept open all of the time, the air will maintain a character practically the same as the outside air. When, however, the windows and doors are kept closed during the cold weather, as they usually are, the matter of maintaining the purity of the air within the house is one which has given, and is still giving all persons interested in Public Health, much concern.

Many forms of ventilators have been devised and with varying degree of success.

The great problem has been to admit a constant change of fresh air from without and still maintain the temperature of the house.

Concerning these problems there have been some radical changes taking place in the minds of many authorities during the past few years.

It would appear from some recent authorities, and their experiments would seem to be conclusive proof of their opinions, that most of our ideas regarding ventilation, contamination of air, and humidity have been quite erroneous.

Studying the peoples of Continental Europe at first hand, as I have had ample opportunity of doing on several occasions, I have been struck by the difference between our theory and their practice. Many of those people have never slept in a room since they were born, nor before, with the window open, and still one is struck with the large numbers of these peoples who live to a ripe old age. Of course one cannot regard this as an argument against ventilation, but on the other hand, if the situation were as bad as we have been taught to believe, and fraught with such great danger, there would not be a single peasant alive today in Continental Europe.

Concerning the present ideas on ventilation and air humidity, I shall quote at length from a recent work on the problem of humidity indoors, by E. P. Lyon, M. D., professor of physiology in the Medical School of the University of Minnesota.

TABLE I

Per Cent Humidity not Allowing for Expansion

Grains per cu.ft.	0°	10°	20°	30°	40°	50°	60°	70°	80°
.5	100%	45%	33%	23%	16%	12%	9%	6%	4%
1.1		100	70	50	36	26	19	14	10
1.5			100	68	50	35	26	19	14
2.19				100	70	50	38	27	20
3.06					100	72	53	40	29
4.24						100	73	53	40
5.82							100	73	54
7.94								100	74
10.73									100

"The air is usually described as a mixture of three gases. Really there are four, nitrogen, oxygen, carbon dioxide and water vapor. While all may vary relatively or actually the proportion of water vapor varies far more than any of the others.

When at any given temperature the air contains as much vapor as possible the air is saturated. Table 1 shows the weight of water in saturated air of various temperatures. Note that at 70°F. the capacity of the air for water is sixteen times as great as at 0°F. and seven times as great as at the freezing point.

"It is evident that if saturated air at 0 degrees is raised to 70 degrees seven and five-tenths grains of water must be added to each cubic foot in order to saturate the air under the new temperature. Or looking at the matter in another way, if air saturated at zero were raised to 70 without addition of water, this air would only be 6 per cent. saturated.

"Every intermediate degree between 0 per cent. and 100 per cent. of saturation is possible at each temperature. Hence, the idea of relative humidity or percentage of saturation. This is the quantity obtained by the dew point or by the rate of evaporation test. It is valuable for certain considerations, particularly when the temperature does not change. But the relative humidity changes with temperature as has been indicated. I am therefore tentatively suggesting the term mass humidity to indicate the total quantity of water per cubic foot of air.

"Since the absolute zero Fahrenheit is minus 459 degrees on the absolute scale, our climatic fluctuations of temperature would be about 25 per cent. The atmospheric pressure varies a few per cent. at any one point and perhaps 30 per cent. among habitable localities, the variation of N_2 is negligible and of O_2 and CO_2, even including our closed houses, is small. But the water vapor may be hundreds of times greater at some time and places than at others.

"At 0°F. it is impossible to have more than one-half grain of water vapor per cubic foot of air. The range of vapor content at 0°F. is so small that I do not believe we could differentiate between cold effects and humidity effects.

"At intermediate temperatures, conditions are still different. With a temperature of 40°F., there is a marked difference between the effect of saturated air and dry air. This is because the saturated air has now a considerable quantity of water (Table 1) and this increases markedly the rate of loss of heat by conduction from the body surface. This is by reason of the high specific heat of water.

"At higher temperatures the high rate of loss through conductivity does not prevail. On a May or June day around 70°F. and 70 per cent. relative humidity we take off some of our clothing and feel fine and comfortable.

"The humidity standards in the hygienic and engineering text books are mere guesses and seem to be founded on moderate summer weather. Sixty per cent. to 70 per cent. relative humidity is a frequent standard. These books were written by people living in more moderate climates than Minnesota in winter.

"My experiments show that in zero weather it is not practical to keep a 60 degree humidity in a building without double windows. Literally streams of water will condense on the glass and run down to the floor. Even with double windows one may get condensation on outside walls and ruined wall paper. I have therefore come to the conclusion that 40 or 50 per cent. is as high a humidity as can be satisfactorily maintained in homes in this State in cold weather. If we accept this tentative standard, what does it mean as a practical problem?

"Let us take a small house of say 10,000 cubic feet capacity. From Table 1, it appears that each cubic foot of zero degree air will need

7.5 grains of water added to it to saturate it when it has been heated to 70°F., or about 4 grains to half saturate it. Calculation shows that about one gallon of water will be needed for the house of 10,000 cubic feet capacity and 50 per cent. saturation. This fact is perhaps startling to one when he approaches this problem mathematically. Practically the problem would be of small significance if you could evaporate your one gallon of water into the air of your house and keep it there. But you can't. There is constant leakage and this is surprisingly large.

"Experiments which I made three winters ago indicated that the air of my well-built and wholly double-windowed house was renewed at least ten times a day in quiet weather. In engineering books twenty-four changes a day are generally assumed. Wind greatly increases the rate of exchange between outside and inside air.

"Suppose that we say that the air in our 10,000 foot house is renewed ten to fifteen times a day. We arrive at the startling fact that 10 to 15 gallons of water must be evaporated every 24 hours if we care to maintain even the moderate humidity this paper advocates. Of course what most people are actually doing is nothing at all, with the result that our houses and offices in winter are often drier than any desert on the face of the earth.

"No quanitative physiological evidence as to the effect of dry air is at hand. We certainly live under artificial conditions. I believe they are bad. I believe that artificial humidification of dwelling houses, offices and other places where relatively few people gather is desirable from the standpoint of comfort and perhaps is considerably protective from infection and from vasomotor strain.

"Do the ordinary home appliances meet the need? If you recall that 15 gallons of water are needed per day, you will see at once that the little dish on the radiator is a delusion. The tea kettle on the kitchen stove may do pretty well for that room but has little effect on the house as a whole.

"There are a good many devices on the market. Are these effective? Let us take up in succession the different types of heating.

"For hot water radiators (also for steam) I know of the following humidifiers, all of which I have tested:

EVAPORATION PER LINEAR FOOT OF RADIATOR OCCUPIED

'Speco,' average of 3 tests, zero weather, grams per 24 hours	294
'Savo,' average of 3 tests, zero weather, grams per 24 hours	230
'Buddington,' average of 3 tests, zero weather, grams per 24 hours	1,116
'Flobun,' average of 2 tests, zero weather, grams per 24 hours	1,248

"None of the manufacturers of these articles seem to have recognized the essential physical principles which are (*a*) large surface of water exposed to the air, (*b*) rapid renewal of air over the surface of the water. The temperature within the limits set by radiator heating is of less importance in securing evaporation than either of the factors mentioned above. Depth of water is of no importance, yet several manufacturers have made their receptacles as deep as possible.

"Attacking the problem with the above principles in mind I have devised several types which are 10 or more times as effective as anything on the market. One of these consists of several trays, one above the other, and so arranged that warm air rising from behind the radiator constantly passes between the trays and over the water surface therein. Twelve trays gives 10 square feet of water surface per linear foot of radiator occupied. One of these apparatuses 30 inches long evaporated 3.7 gallons daily in my house last January.

"Four or five such humidifiers would be sufficient, in our house of 10,000 cubic feet, to meet our tentative requirement of 40–50 per cent. humidity.

"But the apparatus is subject to two criticisms: (*a*) it is bulky and the ladies don't think it is pretty; (*b*) it has to be filled by hand. I put three and one-half barrels into that one in my house during January last. Of course it would be possible to pipe water and waste to each radiator and make the apparatus automatic.

"I worked a long time with drip systems. They can be made very efficient but need a large amount of supervision.

"Last winter I experimented with wick systems. The troubles with those humidifiers on the market which use the wick system are (*a*) too little surface, (*b*) clogging of wicks by deposits from water.

"I have been able to greatly enlarge the surface by arranging close parallel troughs either across or lengthwise to the radiator. A sufficient evaporation is possible by this arrangement.

"So far as the third difficulty—namely, clogging of wicks—is concerned, I find that it is less if the wicks are never permitted to get dry, as they are almost sure to do in any hand-fed system. I also find that cheap wick substance such as blotting paper and the heavy absorbent paper used by botanists as plant driers are just as good as the fancy wicks found in the apparatus sold in stores. These paper wicks can be used for a while and thrown away.

"Unless a slightly efficient automatic humidifier for hot water systems can be worked out along the lines indicated I believe that those who have hot water heating will have to fall back on accessory apparatus such as electric fans to aid evaporation, or special water boilers to put vapor into the air. Such apparatus has been patented but apparently has not proven a success. It would surely be somewhat expensive. Remember you have to face all the time the necessity of evaporating one-third to one-half a barrel of water a day for an ordinary house.

"So far as steam systems are concerned the problem seems easier. There are devices on the market for letting steam out noiselessly into the room. I have not tested any of these but if large enough they ought to be efficient as moisteners. But engineers state that they are dangerous in that they lower the water level in the boiler and that no safe automatic boiler feed is known.

"Another method used in steam systems is to provide steam coils to boil water in separate receptacles. This is free from the previous criticism and ought to be effective, provided said receptacles furnish sufficient free surface of water-air contact and also provided automatic water supply to the humidifiers is arranged.

"The older hot air furnaces often had a small water tank at the base of the air space. This was totally ineffective. I tested one that evaporated less than a quart a day.

"Later types of furnaces have a tank above the fire box. These must be better, but the examples I have seen offer only a small water-air contact and I should want an actual test before endorsement.

"Nevertheless, if I were to put a heating system into a small house in Minnesota in the present state of development of hygiene and of heating engineering I would choose a hot air furnace. I would have no outside air flue, but rather a cold air return flue from every room to the base of the furnace. I would look to this system to secure circulation, which we now recognize as a very important hygienic factor. I would trust for leakage for renewal. I would have double windows, expecting to have even with these ample oxygen for an ordinary family. I would supply moisture by a sufficient number of broad shallow pans just above the fire pot, the water level in these being automatically maintained by connection with the city water system.

"I would have a good psychrometer (or hygrometer) and see to it that the relative humidity was kept above 40 per cent. I would have a good thermometer and keep the temperature at 65°F. even if they did complain. I should expect good health and comfort dividends on the outlay of money and trouble required to get these conditions."

From the above it will be seen that humidity of the air, is under ordinary circumstances, very variable. It will also demonstrate that in order to have the air changed fairly often in a house it is not necessary to keep the windows and doors open. It will suffice under ordinary conditions, except when many persons are in one room at a time, that a window be opened a small amount, perhaps at both top and bottom, which will insure a rapid change of air.

For practical purposes in order to secure warmed air, which is constantly being renewed from without and with a reasonable humidity the hot air furnace has a large superficial receptacle for water which is rapidly evaporated and distributed with the air through the house is by far the most practical plan.

Dust.—In certain localities, and during dry windy weather, dust is extremely irritating, especially to the delicate mucous membrane of children, and particularly if they are suffering from some inflammatory process of the respiratory passages.

It is a difficult matter to prevent dust from entering with the air. It may be diminished if the apertures left open for ventilation be filled with fine cheese cloth screens, several thicknesses, which are kept moist with water. There are devices with which some houses, clubs, etc., are provided which filter all the air before it is heated and forced throughout the building. These of course are impractical for the average home. It will be found that where the air is contaminated with dust an abundance of moisture will greatly lessen this irritating effect upon the mucous membrane.

Location of the Home.—As a matter of general hygiene it is important that the home be built on high ground from which the drainage is good. It is particularly important that the walls of the foundation be so constructed that surface water does not drain into the cellar. To this end the ground should slope away from the house.

Cisterns for the purpose of collecting rain water should be outside of the foundation and should be frequently cleaned, and the water should never be used for drinking purposes unless first boiled. Cisterns should be carefully sealed to prevent the entrance of rats, mice, etc., which frequently are drowned and result in contamination.

Wells for the supply of water to the home should be dug in a place away from any possible contamination from surface water which may drain outhouses or the farm yard.

In localities where there is no city water supply or sewerage system there is no more important factor in the prevention of contagious disease than a water supply which is insured against contamination by discharges from the body. This is particularly true in reference to typhoid fever.

Where there is no sewerage system and privies are necessary they should be located outside the house but should be connected by a covered passage so that it is possible for all members of the family to visit them regularly without undue "punishment." The privy should be located so that the odor is carried away from the house by the prevailing winds. It should be provided with a zinc lined box so that all excreta will be retained therein until carted away, disinfected, and buried. This procedure should be carried out at frequent intervals.

When there is any contagious disease in the house all excreta should first be carbolized before it is ejected into the sewer or otherwise.

Garbage cans should be kept covered as they serve to attract flies and nothing should be put in garbage cans or allowed to be accessible to flies which may be spread by them and may cause disease.

During the fly and mosquito season all windows and doors should be provided with screens and when flies and mosquitoes gain entrance to the house they should be killed at once.

All stagnant water in the form of pools or rain barrels should be eliminated and if this is not possible some crude oil placed on the surface of the water will destroy the larvæ. By this means the Panama Canal was made possible by the federal health authorities.

CHAPTER VIII

HYGIENE OF THE SCHOOL AGE

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SCHOOL HEALTH ADMINISTRATION

Before the beginning of the eighteenth century, education was limited to the church and to a few men outside the church who by dint of unusual intellectual power made their way through a great mass of traditional difficulties to an adequate mental development. The king and his family set the pace for all classes who had cultural ambitions. Court pictures of the family of Charles I, and others though painted a century earlier, represent very fairly the children of the middle seventeen hundreds. Children under the age of 10 are portrayed as corseted, long-skirted formal little miniatures of men and women. Into these degenerate times when education was limited to manners, dancing and rote memory, Rousseau's "Emile" was launched. Rousseau, untrammeled by social tradition, was daring enough to originate ideals of training which were founded on health and natural expression. This was the beginning of a revolution in education developed later by Pestalozzi and Froebel; Pestalozzi by stressing the importance of observation and industrial occupations and Froebel by the adaptation of play, imagination and industrial occupations to the learning process. The influence of these movements upon the health of the developing child has been incalculable. Present-day child study, pedagogy and child hygiene are all based upon it.

The beginnings of education in the United States were exceedingly meager and they varied in different localities with the traditions of the community. Virginia's traditions were aristocratic. Her citizens were either the owners of extensive, isolated plantations which made private education necessary or they were the more or less indigent employees of planters, unable to provide any kind of education for their children.* In Massachusetts, on the other hand, there was no such distinction of classes. The people lived more closely together and each township either organized its own little system, or established schools without system so that, in most communities, children were under school instruction six months in the year. As compared with the best that modern education offers, instruction in the north during the colonial and post-revolutionary periods was very inferior, but, as compared with modern slums there were some hygienic advantages. The population lived in small urban and rural communities, children worked in the open air and were made responsible for work, play was untrammeled, home supervision was intelligent as a rule, houses were exposed to the sunlight and food was simple, sufficient and yet not too refined.

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* See Fisk, John, "Virginia and Her Neighbors."

These fundamental factors in good health are so often lacking in the twentieth century, both in rural districts and in larger cities toward which the population is gradually drifting, that it becomes essential to study modern school conditions. They present problems of school ventilation, heating, lighting, sanitation, bathing, drinking water, nutrition, furniture, books, protection from infectious disease, investigation of physical defects and those phases of education that have to do directly or indirectly with health, such as the study of hygiene, the hygiene of instruction and physical education.

In 1842–1843 France issued a decree for the inspection of schools by physicians.* Sweden made medical inspection mandatory in 1868. She has perhaps the best national system extant, though the city of Brussels is said to have the most thorough and constructive city organization. Scotland passed the "Blind and Deaf Act" in 1890, three years before the passage of a similar bill by England and Wales. This act necessitated a high degree of medical coöperation and was the first movement toward the physical betterment of school children in Britain. In 1903 a commission was appointed in England and Wales to investigate physical training, the necessity of medical inspection and the value of providing food for underfed and impoverished children and in 1907 medical inspection was put into operation.† In 1908 Germany organized and appointed a minister of culture who controls the departments of religion, education and medicine as related to schools.‡

The first law that was passed in the United States relative to school medical inspection was in Connecticut in 1899. In 1906 Massachusetts passed a mandatory law which is the basis of most other bills passed in state legislatures on this subject.‖

Forty states are now organized for medical work in schools. Medical inspection is mandatory in Massachusetts, New Jersey, Rhode Island, Colorado, the District of Columbia, Louisiana, Minnesota, Pennsylvania, Utah, West Virginia, California, Maine, Indiana, Vermont, North Dakota, New Hampshire, Washington, Ohio, New York, Virginia, Maryland, Wyoming, Delaware, Florida, Georgia and North Carolina.

Half of the cities of the United States have medical inspection, and a few of the states have made provision for the medical inspection of rural communities. For the most part, however, children in rural schools, comprising much more than one-half of the school population, have no health supervision except such as the teacher may introduce.

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* Monroe, Cyclopedia of Education.

† Medical Inspection of Schools in Great Britain, Bureau of Education Bulletin No. 49 (1916).

‡ Seeley, "German School System."

‖ Revised Laws Relating to Public Instruction, the commonwealth of Massachusetts, Bulletin of the Board of Education No. 7, whole No. 44 (1915).

The rich State of Illinois, which represents an unfortunately conservative attitude in regard to its school children, furnishes illustrative material of this sort. Cook County, of which Chicago is the county seat, was without organized health work either for the community or the schools until 1918, and there are many counties in the state in which the County Superintendent of Schools has no assistant of any kind, not even a clerical assistant. Some of these men are so hampered by lack of funds that they are powerless to circulate educational literature that comes to them for distribution.

Physical defects and ill health cause 15 per cent. of elimination, 16 per cent. of failures in promotion, and 17 per cent. of retardation among school children.* They are coupled with an increase of poverty, of morbid nervous states in the urban population, and the prevalence of tuberculosis, typhoid, malaria, hook-worm disease, filth, and ignorance of hygiene. In the rural population, this condition exists because the nation, the state, the community, educators, the medical and nursing professions are not, as a whole, cognizant of the true state of affairs.

The Committee on Health Problems in Education of the National Council of Education, and the American Medical Association prepared a public health report through its chairman, Dr. Thomas D. Wood, of Teacher's College, New York, which makes the following statement: "The rural school children are less healthy and are handicapped by more physical defects than the children of the cities including all the children of the slums."† Further, 33 per cent. of the citizens presenting themselves for national defense were unfit for service by reason of serious physical defect.

In the United States, official health departments have been created by the federal government, by states and by local communities. They function under three heads: (1) Coördination; (2) investigation and demonstration; (3) police. The constitution makes no direct mention of any power over the public health. As the needs of the nation have arisen the literal interpretation of the Constitution has been stretched to protect public health and safety in relation to commerce. It includes, therefore, the power to establish quarantine and to deny the right of entry into the country or of transportation from one state to another of objects or persons when that entry or that transportation may, in the opinion of the competent authorities of the national government, endanger the public safety. Congress may also protect federal health by appropriating funds designed for the establishment and activity of police health agencies."‡

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* Rapeer, "School Health Administration."

† ("Health Essentials for Rural School Children," T. D. Wood, 525 W. 120th St., New York City, "Program for the Promotion of the Physical Welfare of Children and the Prevention of Tuberculosis Among Them." S. C. Kingsley, American Medical Association, Chicago.)

‡ Editorial, The Legal Foundations of Public Health Functions, Jour. A. M. A., lxxiii, No. 14 (Oct. 4, 1919).

Public Health Law.—"An Act Granting Additional Quarantine Powers and Imposing Additional Duties upon the *Marine Hospital Service,*"* empowers the Supervising Surgeon General of the Marine Hospital Service to look into quarantine regulations of all State and Municipal Boards of Health and to assist in the execution and enforcement of such regulations. There are also Interstate Quarantine Regulations that restrict the removal of a person with communicable disease from one state to another in public conveyances, unless removal has been granted by state or local health officers at the places of departure and arrival, and unless said person is placed in a separate compartment and accompanied by a properly qualified nurse or attendant who has pledged herself:

1. To avoid communication outside the patient's compartment so far as is possible with the patient's safety.
2. To sterilize all dishes with 5 per cent. carbolic solution, or its equivalent.
3. To collect and destroy by fire or disinfectants all sputum and nasal discharges of patient, and to close the compartment when patient has left it without the removal of any of its contents.† Coördinative control, moreover, goes farther. Each year the Boards of Health of the various states meet with the Surgeon General of the United States and either just before or immediately after there is a conference in or near Washington of "State and Provincial (Canadian) Boards of Health of North America" where public health matters are discussed and codes formulated. Likewise, The Pure Food and Drugs Act of 1906, The Child Labor Act and The Harrison Act relating to the sale of narcotic drugs have passed the scrutiny of the courts.

Of all recent national movements designed to better the health of school children, the most significant are expressed in the passage of two bills, *viz.*, the Fisher Bill, the Smith-Hughes Bill and other bills. England and Wales passed the Fisher Bill in 1918. This provides exhaustively for the physical betterment of school children and preschool children, and includes not only medical inspection but special education for epileptics, the blind, the deaf, the feeble-minded, and for medical treatment, for research, for physical training, for holiday camps, school baths and swimming pools, nursery schools and classes, and allied features more remotely related to health.

In October, 1918, the sixty-fifth congress of the United States passed the Smith-Hughes Bill, which appropriated for the fiscal year ending June 30, 1920, and annually thereafter, $100,000,000 for the abolition of illiteracy, each state to coöperate and provide one dollar for each dollar of Federal money for work within its own confines. Section 15 reads as follows: "That in order to coöperate with the States in the promotion of physical and health education and recreation, two-tenths of the sum annually appropriated by Section II of this Act shall be used for physical education and recreation, the medical and dental examination of children of school age, the determination of mental and physical defects in such children, the employment of school nurses, the establishment and maintenance of school dental clinics, and the instruction of the people in the principles of health and sanitation. The said sum shall be apportioned to the States in the proportions which their respective entire populations bear to the total population of the United States, not including outlying possessions, according to the last preceding census of the United States."

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* U. S. Statutes at Large, xxvi, Chap. 114, p. 944, approved Feb. 15, 1893.

† "Railway Sanitary Code." Washington Government Printing Office (1920).

It will always be necessary to have some coördinative federal jurisdiction of health matters, and centralized investigative and demonstrative functions are certainly important.* Whether government control is desirable in the sense represented by the following bill is quite another matter. So far all such bills have been defeated because, among other objections, they rob local physicians of what seem to be their proper function.

A Bill Establishing a Department of Public Health, July, 1919, Senate Bill 2507. "This provides for a department of public health under the direction of a secretary, who shall be a member of the cabinet, and for three assistant secretaries; the first assistant to be a man trained in medical science, public health and sanitation; the second to be an expert in vital statistics; and the third to be a woman trained in medicine or nursing and public health. The U. S. Public Health Service and the Bureau of Chemistry are to be transferred to the new department, which is also to have bureaus on vital statistics, sanitation, hospitals, child and school hygiene, quarantine, food and drugs, nursing, tuberculosis and personnel. The secretary of public health is directed to communicate with the governor of each state requesting him to recommend to the state legislature suitable legislation with adequate appropriations to secure coöperation between the federal department of public health and the state board of health. Every state taking such action is to be entitled to its proportionate share of such funds as may be appropriated by Congress for carrying out the provisions of the act. The secretary of public health is also directed to divide the United States into health states, districts, subdivisions and precincts, each conforming to the geographical boundaries of the various political divisions. Each state is to create a state board of health with a state health officer and a health officer for each district, subdivision and precinct, the secretary of public health to appoint these state officers as federal health officers so that in each coöperating state every health officer of said state or of each district, country or precinct therein by virtue of his selection by the local authorities becomes also a federalized officer, and as such an integral part of the Department of Public Health. The Department of Public Health is directed to coöperate with the Departments of Commerce, Labor and the Interior in the collection of vital statistics, and to establish a uniform system of cards, records and reports regarding diseases, disabilities, industrial accidents, births, deaths, *physical condition of school children*, the number and condition of existing hospitals, etc. The bill provides for the appropriation of $15,000,000 for 1920 to be prorated among the states in proportion to their population, as soon as the states comply with the provisions of the law and the regulations of the secretary of public health, provided that each coöperating state must contribute to the public health work a sum equal to that contributed by the federal government, and that it must make full and complete reports of births, deaths and morbidity. It also appropriates $48,000,000 for the construction of sanitoriums and hospitals, this sum to be distributed among the states in proportion to their population, each state receiving its allotment to provide an equal amount, also location, plans and means of future support of the proposed hospital."

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* McLaughlin, A. J., The Control of Communicable Diseases, Jour. A. M. A., lxxvii, No. 8 (Aug. 20, 1921), p. 594.

Public Health Law and Administration, as Related to States.—The State Board of Health of many states consists of seven persons, one of whom is the Commissioner of Health or Medical Secretary of the State Board of Health and the head of the Department of Health. This board is appointed by the governor, by and with the consent of the Senate. The State Board of Health or Council may establish or amend sanitary regulations of the *Sanitary Code*, which supersede all local ordinances of cities, towns, villages or consolidated health districts.

The best organized boards have the following divisions:

1.* Division of Administration.
2. Division of Sanitary Engineering.
3. Division of Laboratories and Research.
4. Division of Communicable Diseases.
5. Division of Vital Statistics.
6. Division of Publicity and Education.
7. Division of Child Hygiene.
8. Division of Public Health Nursing.
9. Division of Tuberculosis.

The powers and duties of the commission are:

1. To exercise general supervision over the work of all local health authorities except perhaps in the largest cities.

2. To enforce the public health law and the sanitary code.

3. To make inquiries in respect to the causes of disease, especially epidemics.

4. To investigate the sources of mortality and the effect of localities, employments and other conditions upon the public health.

5. To collect and preserve facts relating to disease, death and health such as may have a future bearing upon the community health and safety.

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* Note.—It will be observed that all of these divisions have some bearing on school health work.

6. To issue subpœnas and to compel the attendance and testimony of witnesses.

7. To reverse or modify orders of local Boards of Health if such orders involve the health of adjacent territory not theirs.

8. To exercise exclusive jurisdiction over all lands acquired by the state for sanitary purposes.*

The State of New York, which may be regarded as a very efficient type of organization, is divided into 20 or more sanitary districts, over each of which there is appointed a sanitary supervisor who is a physician, appointed, directed and aided by the Commissioner of Health of the State of New York.

In many of the states sanitary districts are limited to counties. In some states the board of County Commissioners in counties not under township organization and the supervisor, assessor and town clerk of every town in counties under township organization constitute a board of health who make and enforce rules for promoting the health of the community and controlling diseases dangerous to it. They do not, however, as a rule control incorporated cities or villages.

Great cities have their own organization on the same lines, broadly speaking, as those of the state, subject to the health laws of the state.

In New York State, cities of the third and fourth class have a board of health consisting of the mayor and six other persons, one of whom is a competent physician appointed by the mayor. In times of special emergency a secretary may be employed to receive reports sent in by local physicians and to forward them to the local quarantine officer with a duplicate to the state board of health.

In villages, the local board of health consists of the board of trustees.

In towns, it consists of the town board—or city council. The city marshall is often included.

Some smaller towns, villages and road districts find it advantageous to consolidate. Such districts are called "consolidated health districts" and the board is composed of the supervisor of each town, the president of the board of trustees of each village and the mayor of each city included in the district.

By referendum, the State of Illinois has applied the principle of voluntary self taxation by the voters, for the care of dependent tuberculosis patients in the community. It has been recently suggested† that health centers, under the State Department of Health, be established in adaptable units of population, by the same method which shall include "health inspection of school children, by local personnel, instruction of pupils in personal and general hygiene and the proper application of physical training of children, and other like duties." As the plan for such centers is to include laboratories, a hospital and public assembly rooms for the health instruction of the adult members of the community, it would seem to offer not only "the inquisitorial watchfulness of a higher authoritative body," but protection of the local physician and protection of the public also.

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* "Manual of Health." New York State.

† Billings, Frank, The Future of Private Medical Practice, Jour. A. M. A., lxxvi, No. 6 (Feb. 5, 1921), p. 349.

States and cities of the first and second class embody their health laws in the form of Sanitary Codes. Smaller civic units incorporate theirs in the Cities and Villiages Act.

The police power of a community rests on either public-nuisance or public-welfare ideas in common law and constitutional law;* *i.e.*, an individual may not maintain a public nuisance and a group of individuals may act together for the public welfare, *i.e.*, smallpox.

When the police power is set in motion in its proper sphere the courts have no jurisdiction to stay the arm of the legislative branch of the government, for it is operating in its own particular field where even the courts are powerless to insist upon a procedure consistent with the forms of common law. Some courts have held that the discretion and judgment of administrative officers, while very broad, is not absolutely and in all cases beyond judicial control, but the tendency is away from this doctrine, for, granting the right to question means and methods in one case, the questions of fact upon which the administrative order is based might be raised in every case, and the object of the law, which is to deal summarily to the end that imminent peril may be averted, would be wholly overcome.†

Where a statute gives a discretionary power to an officer to be exercised by him upon his own opinion of certain facts, he is made the sole and exclusive judge of the existence of those facts, and no other tribunal, unless expressly authorized by law to do so, is at liberty to re-examine or controvert the sufficiency of the evidence on which he acted.‡

Mortality at School Age.—In 1913 there were approximately 20,000,000 school children between the ages of 5 and 19 years living in the United States, constituting 20 per cent. of the entire population. Seventy-five per cent. of them were suffering from some partially or completely remediable defect.|| The mortality returns of the United States are limited to the registration area, the population of which in 1911 was 65 per cent. of the total population of the continental United States, the remaining 35 per cent. being composed largely of the rural population. The total population in 1911 was 93,927,000. From the known mortality statistics of the registration it is calculated that there were 100,000 deaths of children within the ages of 5 to 19,** of which

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* Recent judicial decisions in regard to the quarantine of communicable diseases are found reported in Three Washington Decisions 297. From Public Health Reports (Oct. 4, 1918), p. 679. These are quoted in Jour. A. M. A., lxxi, No. 22 (Nov. 30, 1918), p. 1852.

† A decision by the Supreme Court of the State of Washington, Aug. 27, 1918, on the Quarantine of Communicable Diseases. From Public Health Reports (Oct. 4, 1918), p. 679.

‡ A decision by the United States Supreme Court, *ibid.*

|| Allport, Frank, Medical School Inspection, Interstate Medical Journal, xx (July, 1913), p. 637.

** Hoffman, Frederick L., Some Vital Statistics of Children of School Age, Fourth International Congress on School Hygiene, iv, p. 113.

the largest number were preventable. The following table, in which only the most important diseases are listed, is significant.

Table 1.—Total Mortality: U. S. Registration Area 1911 (About 65 Per Cent. of the Total Area)

Diseases	Ages 5–9	Per cent.	Ages 10–19	Per cent.	Ages 5–19	Per cent.
Accidents	2384	13.2	4758	14.2	7142	13.8
Appendicitis	588	3.2	1531	4.6	2119	4.1
Diphtheria and croup	2778	15.3	883	2.6	3661	7.1
Diabetes	153	0.8	464	1.4	617	1.2
Epilepsy	82	0.5	319	1.0	401	0.8
Measles	501	2.8	303	0.9	804	1.6
Meningitis (simple)	368	2.0	302	0.9	670	1.3
Meningitis (cerebrospinal)	240	1.3	217	0.6	457	9.9
Nephritis (acute)	253	1.4	320	1.0	573	1.1
Nephritis (Bright's disease)	239	1.3	707	2.1	946	1.8
Pneumonia (broncho)	622	3.4	336	1.0	958	1.9
Pneumonia (lobar)	530	2.9	1071	3.2	1601	3.1
Rheumatism (acute articular)	419	2.3	627	1.9	1046	2.0
Tuberculosis (abdominal)	142	0.8	374	1.1	516	1.0
Tuberculosis (lungs)	579	3.2	6815	20.3	7394	14.3
Tuberculosis (meningitis)	606	3.3	490	1.5	1096	2.1
Tuberculosis (acute miliary)	106	0.6	544	1.6	650	1.3
Tuberculosis (other forms)	180	1.0	456	1.4	636	1.2
Typhoid fever	747	4.1	2551	7.6	3298	6.4
Organic diseases of the heart	830	4.6	2191	6.5	3021	5.9

It will be seen in Table 1 that the diseases which are primarily infectious—diphtheria, measles, cerebrospinal meningitis, lobar pneumonia and typhoid fever—cause 48 per cent. of the deaths and that those diseases which are generally regarded as secondary to infectious conditions, *viz.*, appendicitis, nephritis, bronchopneumonia, rheumatism and heart disease, cause 12.7 per cent., a total of 60.7 per cent., All of these are, in most instances, preventable.

The economic importance of medical inspection has been demonstrated by the State of Pennsylvania which estimates that $2,000,000 has been saved annually since health work has been organized in her schools. On the other hand, the short-sightedness and inconsistences of some others of our great states are seen in the following figures: Minnesota in 1915 voted $4,300,000 aid to her public schools. At the same time she estimated that 40,000 adenoid, retarded children cost her $1,000,000 per annum. To meet this need, she appropriated only $67,000 to her Board of Health to defray the cost not only of all the adenoid and other physical defects of school children but also of every other item that properly falls under the supervision of Boards of Health.* In 1918—an average year—Illinois estimated the total cost of preventable diseases for her entire population as $155,000,000. About one-tenth of this sum was confined within the limits of school age, from 5 to 19, years and could obviously have been largely reduced by medical inspection.

This enormous waste of health, life and money can be eliminated, but elimination will occur only when medical inspection in schools is made universal, compulsory and thorough. Anomalous as it may appear, compulsory education now stands in most sections of the United States as the producer of compulsory disease, because it requires children to be placed continuously where exposure to infectious diseases is tripled, where over constant, poorly ventilated housing produces insufficient oxygenation of tissues with attendant fatigue and loss of immunity, where close attention to books produces eyestrain, and poor posture and restriction of freedom produces nerve strain. This laxness is by no means confined to rural districts. In the winter of 1918–19, during the epidemic of influenza, an investigation was made of some sectarian schools in Chicago, located in a district reporting an extraordinary number of deaths. It was found that the school rooms measured 16 by 24 feet, there was no artificial heat, the windows were kept closed, and there was dry sweeping. The children were packed as close as possible on benches; 140 in one room, 104 in another and several other rooms ranging from 66 to 90.

Medical Inspection.—There are no settled standards of medical inspection in the United States. Hoag suggests three methods of handling the school health problem:

1. Organization with medical officers and nurses or officer and nurse.
2. Organization with school nurses or nurse only.
3. Organization by the employment of a simple non-technical health survey on the part of the teachers only (a series of questions based upon ordinary observation of physical and mental conditions).†

The functions of medical inspectors may be summarized as follows:‡

1. To prevent the spread of contagious diseases by repeated and systematic inspection of school children and by exclusion of children affected with contagious diseases, followed by isolation.
2. To discover and cure remediable physical defects.
3. To investigate the sanitation of school buildings.
4. To aid in educating teachers, parents and children in school and to aid in personal hygiene.

The Functions of School Nurses.—(1) Superficial inspection of children for minor and major infections.

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* Fox, Carroll, Public Health Administration in Minnesota, U. S. Public Health Reprint No. 223 from the Public Health Reports.

† Hoag, Organized Health Work in Schools, U. S. Bureau of Education, Bulletin No. 44 (1913), pp. 16–24, 41–50.

‡ Allport, State Legislation Concerning the Examination of Children, Eyes, Ears, Noses and Throats, Ophthalmology (July, 1915). Rapeer, "School Health Administration."

2. Treatment of minor contagions and injuries. Teaching parents, pupils and teachers in applied practical hygiene.

3. "Follow up work" in the home to see that defects are corrected; visits with children physically defective to dispensaries, hospitals, dental clinics, etc.

4. First aid to the injured.*

The Functions of Teachers.—(1) The early discovery of communicable diseases.

2. Examination of eyes, ears, teeth, hair, etc.

3. The maintenance of healthful schoolroom conditions (temperature, cleanliness, fresh air, etc.).

American School Hygiene Assn., v, pp. 38–40, 68–69.

Royce, B. Franklin, The Teacher's Function in the Prevention of Communicable Diseases, with Special Reference to Legal Responsibility, American School Hygiene Assn., vi, pp. 91–93.

Crampton, C. W., The New York System of School Hygiene, American School Hygiene Assn., vi, p. 319.

Ludlow, J. L., A Practical Method of Promoting School Hygiene in Small Cities, Fourth International Congress on School Hygiene, ii, p. 530.

Howe, W. A., Examination of the Vision, Hearing and Nasal Respiration of the School Children by the Teachers of New York State, Fourth International Congress on School Hygiene, iv, p. 270.

Organization for Health Supervision in Schools; Health supervision in schools may be under the control of the (1) Department of Health; (2) Department of Education; (3) or jointly under the control of the Department of Health and the Department of Education with an executive officer unifying both. At present the situation is as follows: Of the 20 largest cities in the United States 75 per cent. control school matters through the Department of Health.† In the country at large two-thirds of the school health work is controlled by Boards of Education.‡

I. Advantages of Control by the Department of Health.—(1) Effective control of communicable diseases can only be secured by the department of health, because it alone has specific authority, recognized by the people and supported by the laws of the state, to *establish* and *maintain quarantine outside of school grounds, to enforce vaccinations and to administer antitoxin.*

2. Report of communicable disease goes directly to the Board of Health so that no time is lost in establishing quarantine.

3. Costly duplication of visits to infected houses by both physicians and nurses is avoided.

4. The department of health has better machinery for handling communicable diseases, *viz.*, laboratories, city files, records of former cases of infectious diseases in suspected families, etc.

5. General and local knowledge of community conditions and point of view that accompanies it, *viz.*, that adequate isolation must take precedence over school attendance.

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* Kelly, Helen M., "A Hand Book for School Nurses."

† Evans, W. A., Personal Communication.

‡ Wood, Thomas D., Personal Communication.

This is essential if the mortality from school diseases is to be reduced.

A letter from Dr. Herman M. Biggs, certainly one of the greatest public health authorities in the United States, is here appended.

"I feel that School Medical Inspection should be under the health authorities because all of the communicable diseases which occur in school children come under the health authorities as soon as children return to their homes.

"It is often impossible to deal efficiently with an outbreak of contagious disease when the health authorities are caring for the children at home and the school authorities caring for the children when at school; we have found that there is constant friction, overlapping and inefficiency.

Further, the funds which are available in most communities for health work are limited.

What is most needed everywhere is a really highly qualified man in each community who is responsible to that community for the health work there. Very few communities can provide two such men; if they are able to provide for one and can obtain one they are extremely fortunate."

Herman M. Biggs.

II. Advantages of Control by the Board of Education.—"In all communities, the Board of Education has larger funds and the educational conscience is developed before the health conscience. The teachers also are more directly interested in the children and will as a rule coöperate better with the Board of Education than with the Board of Health.*

It is important to unify all health matters pertaining to the child's school life. The constructive significance of phases of school hygiene other than that of communicable diseases, *viz.*, teaching of school hygiene, physical education, etc., can not be over-estimated and can be better controlled by the Department of Education. Further: in small communities, contagion cannot be hidden. It is doubtless an advantage therefore, if public health and School health can not be combined under one head for small communities to center the health work of the schools in the Department of Education, while in larger communities where the element of communicable diseases is a very formidable problem, health matters in the school should be centralized in the Department of Health.

III. A Coöperative Arrangement Between the Department of Health and the Department of Education.—All public administrators recognize the difficulty of coöperation between departments whose functions overlap. The more enlightened and practical organizations therefore are consolidating allied agencies, based on the principle that classification of government should be *in accord-*

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* Evans, W. A.

QUESTIONNAIRE CONCERNING MEDICAL INSPECTION IN SCHOOLS

(Sent out and compiled by Dept. of Health, Chicago)

	4–21–19 Cleveland	4–18–19 Detroit	4–16–19 Cincinnati	4–15–19 Minneapolis	4–16–19 4–22–19 Philadelphia	4–21–19 New Orleans
1. Does the Health Dept. in your city conduct medical inspection services in						
(*a*) The public schools	No	Yes	Yes	No	Yes	No
(*b*) The parochial schools	Yes	Yes	Yes	On call	Yes	
(*c*) The private schools	....	German Yes	No	On call	No	
2. Does the Board of Education in your city conduct medical inspection service in						
(*a*) The public schools	Yes	No	No	Yes	No	Yes
(*b*) The parochial schools	No	No	No	No	No	No
(*c*) The private schools	....	No	No	No	No	No
3. How much moneys are appropriated for medical inspection service in your city by						
(*a*) The Dept. of Health	Nurses' salaries. Amt. not stated.	$36,700	$22,500	$7,200	$20,400	
(*b*) The Board of Education	$76,750	None	None	$38,900	Dr. $55,000 Nur. $32,000	$6,428.72
4. How many schools are given medical inspection service including examinations for physical defects in your city						
(*a*) Public schools	125	136	118	74	303	88
(*b*) Parochial schools	20 out of 54	41		No	104	
(*c*) Private schools	....	German, only 23	....	No	81	
5. Number of children attending grade schools in your city						
(*a*) Public schools	85,058	93,000	42,000	58,000	203,819	35,109
(*b*) Parochial schools	33,372 12,722 Insp.	41,000	15,000	6,220	65,920	
(*c*) Private schools	....	German. only 2,000	....	1,750	7,000	

6. Number of children who received a physical examination during the year 1918.	Public school	79,857	Comp. 7,539			147,631	
	Parochial school	9,323	Part. 31,173	16,000	11,107	58,958	
	Total	89,180	38,712			206,589	0
7. Of the number of children who were examined how many were found to have physical defects?	Public school def. for	32,918				143,712	
	Parochial school def. for	10,761				30,610	
	Parochial school	4,597	10,330	....	6,775	173,782	0
	Public school	28,300				123,225	
8. Of the children having physical defects how many had defects of sufficient gravity to require treatment?	Public school	28,300				173,782	
	Parochial school	4,597		....	....	116,109	0
	Total	32,897	10,330				
	Total def. cor.	12,544					
9. Of the children who needed treatment how many corrections were obtained?	Public school	11,485				Pub. 45.8 %	
	Parochial school	905	4,023	....	....	Par. 66	
		12,390				62,477	0
10. How many clinics are available for the correction of physical defects in school children in your city 1. dental; 2. nose and throat; 3. eye and ear; 4. others.		1: 9 2: 3 3: 1 4: 10	1: 13 2: 9 3: 9 4: 13	1: 4 2: 5 3: 5 4:	1: 6 2: 4 3: 3 4: 6	1: 20 2: 38 3: 38 4: 27	1: 1 2: 5 3: 5 4: 5
(a) Under the control of the municipality		9 D 1 eye 1 Ortho. 7 TB.	19	4 Dent. 1 Gu.	4	9	2
(b) Under the control of private enterprises		3	8	9	2	114 31	3
11. Number of health officers employed in the medical inspection service of							
(a) Public schools		20	51	12 full time and 4 part time	3 M.D. 3 D.D.S.	66	3
(b) Parochial schools		5		....	....	45	
(c) Private schools							
12. Number of nurses employed in the medical inspection of							
(a) Public schools		32	32	15	35	40	1
(b) Parochial schools		21					
(c) Private schools		....					

QUESTIONNAIRE CONCERNING MEDICAL INSPECTION IN SCHOOLS

(Sent out and compiled by Dept. of Health, Chicago)

	4–19–18 Report for 1917 Buffalo	4–17–19 Toronto, Can.	4–22–19 Los Angeles	4–21–19 Boston	5–12–19 St. Louis	4–25–19 New York City
1. Does the Health Dept. in your city conduct medical inspection services in						
(*a*) The public schools	Yes	Yes	No	No	No	Yes
(*b*) The parochial schools	Yes	Yes	No	No	No	Yes
(*c*) The private schools	Yes	No	No	No	No	No
2. Does the Board of Education in your city conduct medical inspection service in						
(*a*) The public schools	No	No	Yes	Yes	Yes	No
(*b*) The parochial schools	No	No	No	No	No	No
(*c*) The private schools	No	No	No	No	No	No
3. How much moneys are appropriated for medical inspection service in your city by						1917
(*a*) The Dept. of Health	$45,313	Not known, part of general fund	None	None	None	$358,780.98
(*b*) The Board of Education	None	None	$41,000	$67,000	$40,122.58	
4. How many schools are given medical inspection service including examinations for physical defects in your city						
(*a*) Public schools	63 & 15	87	212	All,—16 high, 3 special, 68 elementary districts including about 300 schools	132	513
(*b*) Parochial schools	68	27	None	....	None	214
(*c*) Private schools	8	..	None	....	None	
5. Number of children attending grade schools in your city						

(a) Public schools		53,000	67,643	102,000	In elementary schools 90,000	105,614	758,208
(b) Parochial schools		37,874	7,843	1,800	....	....	138,186
(c) Private schools		2,249	....	400			
6. Number of children who received a physical examination during the year 1918.	Public school	"1917"	14,938				
	Parochial school	26,917	2,069	68,051	104,762	83,607	247,735
	Total		17,007				
7. Of the number of children who were examined how many were found to have physical defects?	Public school def. for		7,782 loss				104,587 teeth
	Parochial school def. for	9,473	1,435 teeth	39,642	61,634	33,211	86,311 other defects
			9,217				190,898
8. Of the children having physical defects how many had defects of sufficient gravity to require treatment?	Public school		7,782		Defects		
	Parochial school	9,473	1,435	25,000	70,660	33,211	190,898
	Total		9,217				
9. Of the children who needed treatment how many corrections were obtained?	Public school		3,386		Defects		12,605 teeth
	Parochial school	3,787	576	18,000	38,132	10,661	52,690 other defects
			3,962				corrected 65,295 T.
10. How many clinics are available for the correction of physical defects in school children in your city: 1. dental, 2. nose and throat, 3. eye and ear; 4. other		1 4 2 9 3 9 4 5	1 20 2 1 3 1 4 1	1 2 2 7 3 8 4 2	1 6 2 3 or 4 3 3 or 4 4 ..	1 2 2 4 3 4 4 4	1 35 2 70 3 77 4 65
(a) Under the control of the municipality		6	20	None	None	None	37
(b) Under the control of private enterprises		3	1	State 1 County 16 B of 2	....	Yes	210
11. Number of health officers employed in the medical inspection service of							
(a) Public schools		25	9	9	1 Director and 45	12	97
(b) Parochial schools			1	0	....	....	
(c) Private schools			0	0	....	....	None
12. Number of nurses employed in the medical inspection of							
(a) Public schools		21	58	11	1 Supervisor and 43	25	250
(b) Parochial schools			7	0	....	....	
(c) Private schools			0	0	....	....	None

QUESTIONNAIRE CONCERNING MEDICAL INSPECTION IN SCHOOLS

(Sent out and compiled by Dept. of Health, Chicago)

	4–29–19 Seattle	4–27–19 Portland	Chicago	4–23–19 San Francisco	4–16–19 Topeka	Denver	Pittsburgh
1. Does the Health Dept. in your city conduct medical inspection services in							
(a) The public schools	No	Yes	Yes	Yes	During flu epidemic		
(b) The parochial schools	No	No	Yes	Yes	During flu epidemic		
(c) The private schools	No	No	Yes	No	No		
2. Does the Board of Education in your city conduct medical inspection service in							
(a) The public schools	Yes	No	No	No	No		
(b) The parochial schools	Occasionally by Catholic physician	No	No	No	No		
(c) The private schools	No	No	No	No	No		
3. How much moneys are appropriated for medical inspection service in your city by							
(a) The Dept. of Health	None	$3,760	H. D. $181,331.13 M. T. S. $ 72,880.06 $254,211.19	$24,253.13	None		
(b) The Board of Education	$30,000	None	....	None	None		
4. How many schools are given medical inspection service including examinations for physical defects in your city							
(a) Public schools	All	60	and branches 377	87	None		
(b) Parochial schools	All infrequent	None	223	20	None		

(c) Private schools		No information	None	42	....	None		
5. Number of children attending grade schools in your city								
(a) Public schools		38,622	35,000	379,127	E. 46,554 H. 4,841 51,495	8,000		
(b) Parochial schools		5,000	None	110,143	10,000	900		
(c) Private schools			None	3,048	....	50		
6. Number of children who received a physical examination during the year 1918.	Public schools	97,000	70,000	69,844	15,423	200		
	Parochial school							
7. Of the number of children who were examined how many were found to have physical defects?	Public school def. for	50,122	....	47,550	4,174	Most of them		
	Parochial school def. for							
8. Of the children having physical defects how many had defects of sufficient gravity to require treatment?	Public school	Defects 50,122	....	47,227	27 %	About ⅓		
	Parochial school							
9. Of the children who needed treatment how many corrections were obtained?	Public school	10,390	....	11,345	15 %	200 tonsils		
10. How many clinics are available for the correction of physical defects in school children in your city: 1. dental, 2. nose and throat, 3. eye and ear; 4. other?		^{1} 1 | ^{2} 1 ^{3} 1 | ^{4} 1	^{1} 1 | ^{2} 1 ^{3} 1 | ^{4} 0	^{1} 11 | ^{2} 16 ^{3} 16 | ^{4} 27	^{1} 4 | ^{2} 4 ^{3} 4 | ^{4}	^{1} 1 | ^{2} 1 ^{3} 1 | ^{4} 1		
(a) Under the control of the municipality		School dent. School clinic	3	6 Dent. 8 M. T. S.	1	Spec. given 2 hr. a week		
(b) Under the control of private enterprises		....	0	56	11	No		
11. Number of health officers employed in the medical inspection service of								
(a) Public schools		2 outside 10 in clinic staff	4	143	4	None		
(b) Parochial schools		1	None			None		
(c) Private schools		None	None			None		
12. Number of nurses employed in the medical inspection of								
(a) Public schools		20	1	119	17	During flu 12 nurses One regular		
(b) Parochial schools		None	None			None		
(c) Private schools		None	None			None		

ance with functioning to be discharged." To secure the maximum good there must be amity between the different departments.*

This principle has been recognized among the child welfare workers in North Carolina, who are organized through the State Board of Charities and Public Welfare, making the county the unit and the Superintendent of Public Welfare responsible for the Juvenile Court, the School, the Probation Officers and the School Attendance Officers.†

An attempt has been made in Chicago to make the work of the Board of Education and the Department of Health more coöperative. The plan is as follows:

1. The Health Commissioner shall be a member of the Board of Education by reason of his office, and shall attend the meetings of the board in the capacity of an adviser.

2. The Superintendent of Schools shall be an assistant Commissioner of Health without salary. He shall attend all councils of the Department of Health in which the health of school children is under consideration.

3. The assistant Bureau Chief in charge of the Division of Child Hygiene of the Department of Health shall be an assistant superintendent of the Board of Education without salary from the Board, the title in the Board of Education to be that of the same officer in the Department of Health. He shall, as an officer of the City Department of Health, have control of the employees under him.

As the chief executive School Officer of the Department of Health he should have an office with the Department of Health for doctors, dentists, nurses, officers in charge of the sanitation of school buildings, and as the chief executive Health Officer of the Department of Education he should have an office at administration headquarters of the Department of Education, where he could advise with the physical education directors, teachers and truant officers. Except in one particular, *viz.*, that the chief in charge of School Hygiene is not directly connected with the Department of Health. Cleveland may serve as a model for cities of the first and second class, *i.e.*, cities of 50,000 or over.

The school health officer of this city has charge of the administration of communicable diseases in the schools, of medical inspection, physical examinations, school dispensaries and dental clinics with hours for consultations with parents of sick children or children with physical defects. He has charge of school nurses, of physical education in connection with which hygiene is taught, of play grounds and summer activities, of the psychological clinic, of special classes for the feeble-minded, the blind, the deaf, and the crippled, of nutritional clinics and school lunches and of the sanitation of school buildings. He is an Assistant Superintendent of schools. A step further would place him on a basis of the highest efficiency, *viz.*, he should be the chief bureau officer of Child Hygiene of the Department of Health which would give him power to administer the control of communicable disease both as a city and as a school official.

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* Newsholm, Sir Arthur, "Conference on Child Welfare." Chicago (1919). Unpublished.

† Bulletin of the North Carolina State Board of Charities and Public Welfare, Raleigh, N. C., ii, No. 1 (Jan., Apr., 1919), p. 5.

A brilliant outline of organization for state work is in vogue in New York state. It includes:

1. Control of communicable diseases in the schools.
2. Physical examination.
3. Physical education.
4. Dental clinics.
5. School nursing.
6. Teaching of hygiene.
7. Hospitalization (temporary for needy cases only).

One medical inspector has charge of all the schools of a township, from 10 to 25. The same type of organization obtains among rural school nurses and definite instructions are issued to teachers bearing upon the examination of eyes, ears and teeth of school children. Most excellent health certificate record forms are issued by the department. Admirable and efficient as is this plan in most respects, it is not generally considered as wholly practical from the viewpoint of communicable disease. In this regard the futility of a double system is nowhere more apparent than in rural districts and scattered communities. Distances to be covered are so great, inclemencies of weather are sometimes so prohibitive and delays of communication between the officers of both organizations so unavoidable that a high grade of efficiency cannot be expected.

The Department of Health should be in close communication with the truant officers who should be required to report to it all cases of communicable disease, diagnosed, suspected or discovered by them on their daily rounds and not already placarded, as well as all violations of quarantine.

A chief medical officer should have been thoroughly trained in medicine, especially in public health, and should also have a practical working knowledge of dentistry, of nursing, of physical education, the ground work of psychology and the problems of the special child, of pedagogy, of nutrition, of the architecture and sanitation of school buildings and some knowledge of industrial problems and of administration. Such positions require persons of wide experience, executive ability and scholarly attainments. Some of our greater medical institutions, notably Johns Hopkins, are providing such opportunities.

Ernest Bryant Hoag* outlines an efficient method of organization for a city of 60,000 school children (300,000 actual population):

One chief health director.
One general medical officer.
One eye, ear, nose and throat specialist.

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* Organized Health Work in Schools, U. S. Bureau of Education, Bulletin No. 44 (1913).

One specialist in mental and nervous diseases and experienced in psychological methods.

One emergency physician also giving instruction in hygiene and first aid.

One woman physician in charge of high school girls and giving instruction in hygiene.

Such a plan would require a central office of several rooms—one general reception room, one private office for the director, one examining room, and one laboratory equipped with medical and psychological apparatus. There should be a medical and dental clinic either in connection with the schools or with some other organization. With this plan in operation, parents of children with physical and mental defects have the opportunity of taking their children to the general offices for special examinations. The different specialists keep office hours on different days of the week, thus giving careful and deliberate attention to such school children as require it. Children needing treatment are referred to clinics. There should be one school nurse assigned to each school physician. The plan proposed presupposes preliminary physical examinations on the part of nurses and teachers.

In school communities of 6,000, to 8,000 the work can be done satisfactorily by half time of one physician and two or more well-trained nurses. In school communities of 8,000 to 12,000, there are needed the entire time of one physician, half time of an assistant and three or more nurses. In school communities exceeding 12,000 there should be an additional half-time school medical officer for each 6,000 increase and one school nurse on full-time for the same number. New York State allows one medical inspector to each additional 3,000 and one school nurse to each additional 1,500. The assistance of teachers becomes necessary in the preliminary examination of eyes, ears, teeth, mouth breathing, contagious eye and skin diseases, and teachers can be easily trained in these details. Rapeer ("School Health Administration") advises as the proper annual quota for a nurse 4,000 individual inspections, 200 class room inspections, 1,000 home visits, 500 treatments given by the nurse herself, and 300 patients taken by her to the dispensary. Her hours should be from 8.30 a.m. to 4:30 p.m. every week day except Saturday when work ends at noon. For further information as to the duties of the nurse see W. A. Howe.* Trained school nurses may be secured through the Department of Nursing and Health, care of Miss M. A. Nutting at Teacher's College, Miss E. P. Crandall, Executive Secretary of the national organization, 52 East 34th Street, New York City, Miss Edna L. Foley, Superintendent of the Visiting Nurses Association, 104 South Michigan Avenue, Miss F. F. Clement, 713 Union Trust Building, Washington, D. C. (Red Cross Rural Nursing Service), the Boston District Nurses Association with the Boston School for Social Workers, and Phipps

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* The System of School Medical Inspection in New York State, American School Hygiene Association, Proceedings of the Tenth Congress, vii, p. 194.

Institute of Philadelphia. The Cleveland Visiting Nurse Association is in affiliation with the Western Reserve University.*

The Expense of Medical Officers.—In the United States this expense is borne by the district, by the school authorities or by the state. In first and second class cities 50,000 to 500,000 and upward: District (if mandatory).

In third class cities 30,0000 to 50,000: School authorities.

In fourth class cities, less than 5,000: State Department of Health.

The salaries of medical inspectors are as follows:

Full-time health officer $2,500 to $5,000 or more.

Part-time health officer $1,200 to $2,000.

If less than a half day, not less than 50 to 75 cents should be paid for each physical examination.†

Nurses' salaries range from $125.00 to $150.00 a month, depending on the length of service.‡

The medical office should be at least 15 feet square, with a comfortable waiting room outside, and a smaller examining room adjacent. It should be in the basement, or near an entrance on the first floor. The room decoration should be in a light color, and it should be kept scrupulously clean. The following book gives valuable information:

Brainard, Annie M., "Organization of Public Health Nursing."—Macmillan, 1919.

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* Rapeer, "School Health Administration."

† Hoag, "Organized Health Work in Schools."

‡ Health Work in the Public Schools, Cleveland Survey.

EQUIPMENT

One desk
Filing cases
Examining table, 6 × 2 feet.
Book case for books and instruments
Long mirror
Stethoscope
Eye charts: Snellen card with reading type in graded sizes; Maddox rods for heterophoria.
Ear speculum
Nasal speculum
Scales
Stadiometer
Spirometer
Dynamometer
Tape measures
Calipers for chest measurements
Wooden tongue depressors
Wooden mouthpieces for spirometer
Microscope
Centrifuge
Stains and slides
Dare hemoglobinometer, or Tallquist
Blood counting apparatus
Culture media and throat swabs
Nitric acid (pure)
Acetic acid, 2 per cent.
Haines' solution
Litmus paper
Johnson & Johnson's emergency cabinet, or:
  Absorbent cotton
  Sterilized gauze (1-yard length)
  Bandages, straight and triangular
  Adhesive tape
  Thin boards or heavy cardboard for sprains
  One artery forceps, 4-inch
  Scalpel, small
  Scissors
  Tweezers
  Surgical needles
  Silk or catgut (fine)
  Ordinary needle and thread (coarse)

Six thermometers, clinical
One sterilizer (electric)
One pus basin
One white enamel basin (8 × 3 inches)
Hot water bag
Birmingham douche (nose)
Medicine dropper
Toothpicks for applicators
Tr. iodine (disinfectant for wounds)
Alcohol
Carbolic acid
Lysol
Boric acid (saturated solution, powder or crystals)
Hydrogen peroxide
Picric acid (burns)
Sanitas jelly
Sterilized vaseline
Tr. iodine, 1 part
Glycerine, 9 parts } throat application
Oil of cloves (toothache)
Glycerine, 95 parts
Carbolic acid, 5 parts } earache
Argyrol 20 per cent.
Glycerine 80 per cent. } eye infections
(Fresh solution necessary)
Adrenalin 1–1,000, P. D. and Co., epistaxis.
Normal salt solution (nose irrigation)
Strychnine sulphate tablets, gr. 1/60
Aromatic spirits of ammonia
Soda bicarbonate
Sulphur ointment 10 per cent. or,
Ammoniated mercurial ointment, 10 per cent.
Elix. sod. bromide
  Acetanilid,
  Heroin,
  in pill form
  Sig. One every three hours } Dysmenorrhea

ORGANIZATIONS CONTRIBUTING TO SCHOOL HYGIENE

1. *National Bureaus, Department of the Interior, Bureau of Education:* bulletins and bibliographies.
    Treasury Department, The Bureau of Public Health Series; Surveys of rural health.
    The Department of Labor, The Children's Bureau; School Health Surveys.
2. *National Organizations:*
    International Congress of School Hygiene.
    The American Medical Association (Council on Health and Public Instruction).
    Health Foundations, endowed by Rockefeller, Sage, Carnegie and others.
    The National Education Association.
    The National Association for the Study and Prevention of Tuberculosis, Infant Mortality and the Feeble-Minded.
    Child Health Organization.
    Congress of Sanitary Eugenics.
    National Associations for Conservation of Vision, Sanitary and Moral Prophylaxis.
    The National School Hygiene Association.
    The Playground Association of America.
    Committee of One Hundred on National Vitality.
    National Consumer's League.
    The Red Cross.
3. *Local Organizations:*
    Christian Associations.
    Settlements.
    Bureaus of Municipal Research: New York.
    Bureau of Educational Experiments: New York City.
    Chambers of Commerce.
    Child Welfare Organizations.
    Ohio Institute for Public Efficiency: Columbus, Ohio.
    The Elizabeth McCormick Fund: Chicago.

There should also be coöperation with dispensaries and boards of education in the purchase of eye glasses, drugs, braces and other apparatus,* with charity officials and institutions for defective and delinquent children, with police and juvenile courts, with departments of physical education, domestic science and school sanitation, with officers of supply departments in regard to the hygiene of textbooks, with dentists, with doctors, parent teachers associations, visiting nurse associations, social service organizations, infant welfare societies, tuberculosis institutes, and with the General Safety Committee of the Surface Lines.†

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* Correction of Defects Among School Children, American School Hygiene Association, vii, p. 150.

† Educational Hygiene, Department of the Interior, Bureau of Education, i (1915), ch. 17, pp. 411–13.

Lectures and exhibits on health are also of the greatest importance and can be conducted by Parent Teacher Associations, the Red Cross, Child Welfare Organizations, Societies for the Prevention of Tuberculosis, etc.

For further information, see:

Public Health Administration in Minnesota, Reprint, 223, from the Public Health Reports, U. S. Public Health Series and the American School Hygiene Association, vi, p. 67.

Ayers, L. P., and Ayers, May, Health Work in the Public Schools, Cleveland Education Survey.

County Health Work, Jour. A. M. A., lxxi, No. 17, p. 1378.

American School Hygiene Association, vi, p. 303.

American School Hygiene Association, v, p. 61.

Foster, I. A., M. D. and Fulmer, Harriet R. N., Health Survey of White County.

For hospitalization, see:

Baker, J. S., Bulletin of Health, New York City, Division of Child Hygiene Monograph Series, No. 4 (August, 1913), pp. 101–02.

Allport, Frank, Health Work in Public Schools, Cleveland Education Survey, p. 24. State Legislation Concerning the Examination of School Children's Eyes, Ears, Noses and Throats, Ophthalmology (July, 1915).

Rapeer, "School Health Administration."

Howe, W. A., The System of School Medical Inspection in New York State, American School Hygiene Association, vii (1917), p. 176.

COMMUNICABLE DISEASES

The following are regarded as communicable diseases by the Department of Health of New York State: Chicken pox, diphtheria, epidemic cerebrospinal meningitis, epidemic influenza, epidemic or septic sore throat, German measles, measles, mumps, poliomyelitis, scarlet fever, smallpox, trachoma, and pertussis.

Medical inspection in schools was organized primarily to combat the spread of infectious diseases, on account of the intimate and repeated contact of school children, and the greater susceptibility of persons of school age, and the unquestionable fact that they carry these diseases into their homes. Laws and regulations have been gradually developed which now aim to govern national, state, county, municipal, village and rural school units in regard to the control of cummunicable diseases.

The lack of efficiency in carrying out these laws, and the unreliability of the figures, may be seen by the following tables:

TABLE 2

	Chicken-pox	Diphtheria	German measles	Measles	Mumps	Scarlet fever	Whooping cough	Total
A	551	128	151	934	644	244	679	3,331
B	65	151	0	80	24	38	8	366

British Medical Journal.

A, the estimated number of contagious diseases occurring in London, 1915.

B, the actual number of contagious diseases reported in London, 1915.

This inaccuracy is due either to inadequate legislation, to lack of funds, or to lack of coöperation from physicians who do not report their cases.

Mortality statistics are far more reliable and show an improvement in the control of communicable diseases.

Mortality statistics of school communicable diseases in the United States from 1900 to 1913:

TABLE 3.—DEATH RATE PER 100,000 POPULATION

	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913
Diphtheria and croup....	43.3	34.0	30.8	31.7	28.3	23.6	25.7	23.6	21.5	20.4	21.4	18.9	18.2	18.8
Scarlet fever............	10.2	13.1	12.6	12.2	10.8	6.7	7.7	10.0	11.9	11.4	11.6	8.8	6.7	8.7
Measles.................	12.5	7.3	9.5	9.8	11.0	7.5	12.2	10.0	9.9	9.6	12.3	10.0	7.0	12.8
Whooping cough........	12.1	9.7	12.0	15.8	6.5	19.6	15.1	11.3	10.6	9.6	11.4	11.3	9.3	10.0

The death rate is not the only serious phase of the problem. While it far outweighs all other considerations, interference with school attendance is also a public problem of no mean importance. In families where there are several children, it is not uncommon for a child to lose two or three months out of the school year on account of sickness of this type. This is especially true of city schools.

The high incidence of communicable diseases in children of school age is seen in the following table, which shows at the same time the gradual development of public immunity:

TABLE 4.*—SHOWING THE PERCENTAGE OF CHILDREN AT EACH AGE WHO HAVE ALREADY SUFFERED AN ATTACK OF COMMUNICABLE DISEASE

Age	Chicken-pox	Diph-theria	German measles	Measles	Mumps	Scarlet fever	Whooping cough	Total
Under 1	0.7	0.0	0.0	0.0	0.0	0.0	6.0	6.7
1	8.0	0.0	0.0	4.0	1.0	0.0	14.5	27.5
2	11.2	0.8	1.2	10.4	4.8	0.8	19.9	49.1
3	18.8	0.8	3.1	22.0	5.1	3.9	25.9	82.6
4	22.1	1.5	2.0	33.7	11.1	5.1	38.6	112.1
5	27.3	1.7	4.4	35.5	9.4	5.3	42.7	128.3
6	32.6	2.1	6.3	49.7	17.3	5.9	55.7	169.6
7	40.4	2.4	4.7	60.3	23.0	11.5	58.0	200.3
8	39.8	3.1	8.4	71.2	27.7	12.2	59.6	222.0
9	46.0	5.7	9.9	79.5	38.1	10.0	60.8	250.0
10	49.2	6.4	9.3	79.3	39.8	15.4	65.3	264.7
11	49.9	7.7	12.9	80.4	50.9	18.2	63.2	283.2
12	50.8	10.9	12.7	82.9	50.9	21.7	64.0	293.9
13	51.9	11.6	15.2	85.0	57.1	23.6	64.7	309.1
14	57.0	11.7	15.3	82.6	49.7	26.0	60.6	302.9
15	52.3	13.9	13.1	84.2	52.5	26.7	60.0	302.7
16	53.1	14.7	17.2	82.2	54.4	28.5	61.8	311.9
17	55.8	13.3	15.0	83.3	53.2	26.2	62.2	309.0
18	51.2	17.6	12.9	81.8	45.9	24.7	54.7	288.8
19	58.3	16.7	20.1	84.0	60.4	30.6	63.2	333.3
20	47.4	17.0	17.0	82.1	51.3	28.9	51.3	295.0

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* Henderson, E. C., A Census of Contagious Diseases of 8,786 Children, American Journal of Public Health, London, Canada.

The following chart, computed from the U. S. Census Report, shows that the opening of schools in the autumn increases diphtheria in *all* children, both of school age and those under school age; predominantly, however, in school children. This is as true of scarlet fever.* In fact, the major contagious and other less formidable infectious diseases are so closely correlated with school attendance that they are popularly known as "School Diseases."

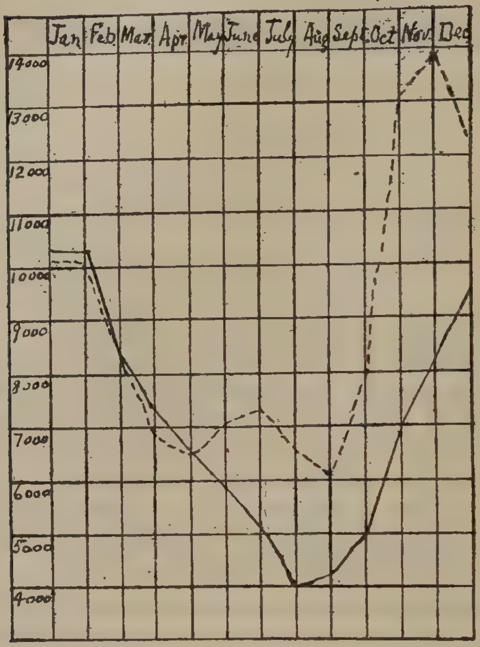

CHART 1.—The broken line shows the number of cases among school children five to fourteen years old during 1900–04 in the registration area of the U. S.

The unbroken line shows the number of cases among children from birth to five years of age for the same period and area. From Medical Report of the Durand Hospital, G. H. Weaver, March, 1913 to March, 1918.

E. O. Jordan† says: "Measles is undoubtedly a school disease. In an outbreak of measles in the Elementary School of the Department of Education of the University of Chicago, while about one-half of the school population was susceptible, 66 per cent. of the susceptibles in two grades were attacked, and less than 10 per cent. in the rest of the school. The children in the two grades affected had been associated in the rehearsal of a play, and during this period one child in the early stages of measles was attending the sessions in her grade. All but one of the primary cases were in these two grades, and 6 of the 10 secondary cases occurring in other members of the school were in families in which a primary case had occurred. Experiences of this kind are of common occurrence in the public schools of cities."

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* Place, E. H., Relation of Diphtheria-scarlet Fever to School Session, Fourth Congress of School Hygiene, iv, p. 521.

† Fourth Internatl. Congress of School Hyg., iv, p. 555.

In the rural schools of the United States, in which more than half the population receives its school training, conditions as regards infectious diseases are more favorable. This was well illustrated during the recent war, and can be seen in the table below. It represents in a measure school, as well as army, conditions.

TABLE 5.—URBAN AND RURAL DEATH RATES. ANNUAL RATE PER 100,000—1915

	Measles	Scarlet fever	Diphtheria and croup	Pneumonia	Pulmonary tuberculosis
Cities in registration states......	7.1	4.0	17.5	156	134
Rural part of registration states....	3.4	3.1	12.9	106	112

Vaughan and Palmer, Communicable Diseases in the U. S. Army, Jour. of Laboratory and Clinical Medicine, iii (Oct., Sept., 1917–18).

Other conditions affecting immunity as shown by Dr. S. J. Baker,* are tenement houses, and control in the school of light, air, pencils, drinking cups, cloak room and washing facilities.

Control of Communicable Diseases.—There are two great principles that must be constantly held in mind when considering this matter:

1. Maximum safety.
2. Minimum loss of school time.

Isolation is at present the only practical method known that can be used to control the spread of infectious diseases. It is impossible to lay down fixed rules for isolation. Experience has shown that certain time limits and procedures are safe and necessary for all conditions; while, on the other hand, there must be considerable latitude allowed for variation in the handling of these diseases in urban communities, rural communities, and in epidemics of differing intensity. In serious epidemics the Department of Health of most states is at the service of local physicians for authority, advice and other assistance. Even in urban communities there are different types of schools, *viz.*, public, parochial, and private. In public schools of cities with a population of 5,000 or more, one medical inspector is responsible for about 4,000 children. In private schools, and in towns with a population of less than 5,000, one medical inspector is responsible for 1,000 children or less. In parochial schools no provision is made, unless the Department of Health of the city assumes it. Rural schools are so isolated that it is necessary that teachers be made responsible for the early detection of communicable diseases.

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* Control of Communicable Diseases in School, Am. Jour. of Public Health.

Rules Governing Communicable Diseases.—Susceptible children and teachers *exposed at home* are excluded during the entire incubation period, counting from date of last exposure.

Susceptibles *exposed at school* are allowed to attend as before, but the room or grade is placed under room quarantine.

If it is possible, as soon as a case occurs, the parents of children exposed should be informed at once as to the facts of infection and dates of danger, and asked to decide whether or not their children shall risk further danger of infection by attending school during this period. In large public school systems it is not possible to send this information, but parents in such systems should be given to understand that this policy has been adopted by the Department of Health, and children should be instructed to inform their parents when their rooms are in quarantine. This gives the parents a sense of assurance that proper protection is being provided. Procedures of such mildness may seem questionable, but it has been shown that in all light epidemics of scarlet fever, diphtheria, whooping cough, etc., children over six years of age may be allowed to remain in school with safety, if they are carefully watched, or properly cultured, and promptly excluded when necessary. This is not true of kindergarten children.*

Suspicious susceptibles among public school children of large cities are reported at once to the medical inspector, who sees the child and then investigates the home, assuming at once the entire responsibility. In New York City children absent more than three days for any unassigned cause are visited by the school doctor in their homes. This is called "Absentee doctoring," and is a prophylactic measure of great value. This is done in selected cases by the Department of Health of Chicago.

In rural schools the teacher alone is in a position to connect the health officer with suspects or sick children. Rural districts are now very generally provided with telephones, so that the situation can receive prompt attention.

If epidemics are highly virulent, of if there is *cross infection* causing great mortality, it may in rare instances be necessary to *quarantine schools*. If so, to be of value, susceptible children must also be quarantined at home. The latter can only be done effectively in small communities under the direct sanction of the Department of Health either of the state or of the community. Such isolation is impossible in great cities, and in almost all cases is unnecessary and undesirable. With medical inspectors, nurses, and intelligent teachers it is usually possible by alertness and close inspection, in the early stages of measles, scarlet fever, German measles and mumps, to discover their onset before harmful contact occurs. This is much more possible in school than out of it. It is for this reason that school quarantine is rarely justifiable.

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* Schmitt, Emil A., "New Regulations for the Control of Infectious Diseases in Some of the Private Schools of New York City." Fourth International Congress of School Hygiene, vol. iv., p. 643.

TABLE 6.—THE FOLLOWING IS A SIMPLE TABLE FURNISHING DATA OF INCUBATION, SYMPTOMS, LENGTH OF QUARANTINE, ETC.

	Incubation period. School attendance		Signs and symptoms*	Length of eruptive stage, days	Termination
	Safe period, days	Unsafe period, days			
Chicken pox.....	1–10	11–21	"Sometimes begins with feverishness, but is usually very mild and without sign of fever. Rash appears on second day as small pimples, which in about a day become filled with clear fluid. This fluid then becomes matter, and then the spot dries up and the crust falls off. May have successive crops of rash until tenth day.	1–4	When crusts are shed (usually 10–14 days)
Diphtheria......	0	1–10	Onset insidious, may be rapid or gradual. Typically sore throat, great weakness and swelling of lymph nodes in the neck, about the angle of the jaw. The back of the throat, tonsils, or palate may show patches like pieces of grayish-white kid. The most pronounced symptoms are great debility and lassitude, and there may be little else noticeable. There may be hardly any symptoms at all." Leucocytosis 6,000–40,000.*		Until recovery and two cultures from nose and throat with no diph. bacilli
Measles.........	1–4	5–18	"Begins like cold in the head, with feverishness, running nose, inflamed and watery eyes, and sneezing; small crescentic groups of mulberry-tinted spots appear about the third day; rash first seen on forehead and face. The rash varies with heat; may almost disappear if the air is cold, and come out again with warmth." No leucocytosis or leucopenia.†	4–7	14 days maximum
German measles..	1–8	9–21	"Illness usually slight. Onset sudden. Lymph nodes back of ears enlarged. Rash often first thing noticed; no cold in head. Usually feverishness and sore throat, and the eyes may be inflamed. Rash something between measles and scarlet fever; variable." No leucocytosis or leucopenia.	2–7	10–14 days
Mumps.........	1–13	14–23	"Onset may be sudden, beginning with sickness and fever, and pain about the angle of the jaw. The glands become swollen and tender, and the jaws stiff, and the saliva sticky.	7–10	Until swelling has subsided; 14 days maximum

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* Cabot, "Clinical Examination of the Blood."

† Hamburger, Münch. Medicinischer Wochenshrift, ix (1913), pp. 1203 and 2120.

TABLE 6.—*Continued*

	Incubation period. School attendance		Signs and symptoms*	Length of eruptive stage, days	Termination
	Safe period, days	Unsafe period, days			
Scarlet fever.....	0	1–8	The onset is usually sudden, with headache, languor, feverishness, sore throat, and often vomiting. Usually within twenty-four hours the rash appears and is finely spotted, evenly diffused, and bright red. The rash is seen first on the neck and upper part of chest, and lasts three to ten days, when it fades and the skin peels in scales, flakes, or even large pieces. The tongue becomes whitish, with bright red spots. The eyes are not watery or congested." Leucocytosis marked.	2–5	Five weeks, cessation of discharges, and complete desquamation
Smallpox........	Vaccination imperative	1–20	"The illness is usually well marked and the onset rather sudden with feverishness, severe backache, and sickness. About third day a red rash of shot-like pimples, felt below the skin, and seen first about the face and wrists; spots develop two days later, then form little blisters, and after two days more become yellowish and filled with matter. Scabs then form which fall off about the fourteenth day." Leucocytosis.†	3–10	Till all crusts disappear
Sore throat, acute septic.	1–3	.....	"Begins with sore throat and weakness. Throat diffusely reddened and may show patches like diphtheria.		
Whooping cough.	1–3	4–14	Begins like cold in the head, with bronchitis and sore throat, and a cough which is worse at night. Symptoms may at first be very mild. Characteristic "whooping" cough develops in about a fortnight, and the spasm of coughing often ends with vomiting." Leucocytosis. Absolute and relative lymphocytosis.	....	Five weeks from date of first whoop

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* Taken from Rules of the New York State Department of Health for Isolation and Exclusion from School. Herman S. Biggs.

Disinfection of the person must be performed on termination of all infectious diseases.

During the unsafe period of incubation susceptibles exposed in school may continue attendance but there should be daily room inspection.

† Cabot, "Clinical Examination of Blood."

Hektoen, L., (1) Summary "The Bacteriology of Measles," Jour. of the Amer. Med. Assn., lxxi (Oct. 12, 1918), pp. 1201–1205; (2) "Experimental Measles," A Review from the John McCormick Institute for Infectious Diseases; (3) "Prophylactic Measures to be Observed in Measles," Jour. of the Amer. Med. Assn., lxxi, No. 8, p. 659.

Violle, H., "The Influenza Epidemic," Presse Medicale. Abstract from Jour. A. M. A., lxxi, No. 23 (Dec. 7, 1918), p. 1945.

Weaver, G. H., Medical Report of Durand Hospital, Chicago, p. 5.

Room Quarantine.—Pupils under room quarantine should be required to come to school a little late, to go directly to their rooms, and should not be allowed to mingle with other children at assembly, at recess time, or at the lunch hour. They should be sent home earlier than the rest of the school. Room quarantine in the case of rural schools involves, as a rule, the entire school. It is usually advisable, whatever the type of school, to exclude susceptibles sitting within five feet of the patient, and his intimate neighborhood, and school friends.

Method of Infection.—This is in all cases through discharges of the nose and throat, and occurs in the early stages of the disease. If scales or crusts exist, infection may occur through them. Distant aerial infection may occur in measles, chicken pox, smallpox, and scarlet fever.

Haven Emerson,* recognizing the tendency of parents to conceal cases of contagion in their families on account of a desire to keep their susceptible children in school, advocates an earlier reinstatement. He quotes the experiments of Anderson and Goldberger† with measles in monkeys. They found that measles could be transmitted at least 24 hours before the appearance of the rash, and that they could not be transmitted later than 24 hours after the appearance of the rash. The earlier experiments‡ of Ludvig Hektoen in 1905 have additional weight because they were made upon the human subject. Dr. Hektoen found that the period of infectivity in man was during the first 30 hours after the appearance of the rash. On this ground, New York City now terminates the case five days after the appearance of the rash, and errs on the side of safety in excluding all children with catarrhal symptoms, especially during epidemics. As correct diagnoses occur in 80 per cent. of exclusions for suspected communicable diseases, the Department of Health believes that the loss of school time suffered by the 20 per cent. is warrantable. The handling of scarlet fever also has been modified. Instead of 42 days, the quarantine period has been established as 30 days, even if the child is still desquamating. Discharges from the nose, throat, or ears, however, are regarded as an indication which requires isolation. So also Emerson would re-admit children to school two weeks after the appearance of the first whoop in pertussis.

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* The Basis of a Reasonable Quarantine of School Children, American School Hygiene Association, vi, p. 207.

† Recent Advances in Our Knowledge of Measles, American Journal of Diseases of Children, vol. iv (1912), p. 20.

‡ Experimental Measles, Jour. of Infectious Diseases.

In all schools the following procedure instituted at the beginning of the year will be found helpful: As parents enter their children in school, the pupil's personal history in regard to communicable diseases should be accurately recorded on separate sheets kept for the purpose, or on the physical examination cards. From this data a communicable disease chart of each room may be plotted, one copy retained in the office, and another sent to the corresponding teacher.

Chart 2.—Communicable Disease Room Chart

Grade 6-B Miss Webster, teacher	Chicken pox	Diphtheria	Ger. measles	Measles	Mumps	Scarlet fever	Whooping cough	Smallpox	Vaccinated	Typical date	Atypical date
Ayres, Charles..........	x	..	..	x	..	..	x	..	..	1912	
Adams, Adelaide........	x	..	..	x	x	..	x	..	..	1912	
Ames, Louise............	x	..	..	x	..	x	..	..	..	1905	
Babb, George...........	..	..	..	x	...	..	x	..	..	1908	
Davis, Eugenia..........	x	..	..	..	x	..	..	..	..	.....	1912
Davis, William.........	..	..	x	..	..	..	x	..	..	....	1914

Such a chart makes it possible to see at a glance the group status of any disease in question.

Where telephonic communication is available between the school and the parents and the problem not too large to handle, each teacher should send, every morning before 10 o'clock, a written list of the names of her absent pupils to the medical office. In private, and third and fourth class town schools, with telephone service, the cause of absence can be obtained from the parents within an hour. In rural districts it would require a very few minutes.

If the case proves to be communicable, and the school affords an office secretary, the following items should be ascertained as soon as possible from the parents and the school: (1) Disease; (2) Name of pupil; (3) Address; (4) Telephone; (5) Grade; (6) Teacher; (7) Pupil teachers (if there are such); (8) Close school associates; (9) Other children in the family; (10) Children of the family in school; (11) By whom exposed; (12) When exposed; (13) Last attendance; (14) Date of onset; (15) Symptoms; (16) Date of rash; (17) Dates of supervision of grade exposed; (18) Other grades involved; (19) Susceptibles excluded; (20) Cultures; (21) Physician; (22) Health officer; (23) Milkman; (24) Room fumigation; (25) Quarantine; (*a*) family, (*b*) school; (26) Termination notice, Department of Health; (27) Return to school; (*a*) satisfactory, (*b*) unsatisfactory; (28) Final return.

With this knowledge, either in part or as a whole, the school is equipped with information which will aid in protecting the pupils and the community.

Exclusions followed up. As soon as a child is excluded from school on account of a contagious disease, the case is reported to the Department of Health, and is followed up within 24 hours by a community health officer, who makes the final diagnosis, and quarantines if necessary. The Department of Health in return sends a card of notification to the school, stating the date at which the child may be re-admitted.

Room Inspection.—Room inspection should occur daily during the dangerous part of the incubation period only. This is 11 days after known exposure in chicken pox, nine days in German measles, five days in measles, 14 days in mumps, four days in whooping cough, beginning at once in scarlet fever and diphtheria.

Inspection thus occurs from the tenth to the twenty-first day in chicken pox, from the first to the tenth day in diphtheria, from the fifth to the eighteenth day in measles, from the first to the eighth day in scarlet fever, from the ninth to the twenty-first in German measles, from the fourteenth to the twenty-third day in mumps, and from the fourth day in pertussis.

Note.—Without exception these periods have proven reliable in the author's experience in over four years of careful watching.

Inspection consists of an examination of the throat with individual wooden tongue depressors, and inspection of the face, neck and hands, and body if necessary. Exposure of the body is legally permissible in examination for contagious diseases, but care should be taken, of course that the child is protected from the observation of other children. Cervical and parotid glands are palpated. Temperature is only taken in suspicious cases.

The significance of temperature in children returning to school after absence, or those who are under daily inspection, may here be considered. Dr. I. A. Abt's* study shows that even with the stability of the heat center in adults there may be a rise in temperature directly proportioned to the violence of exercise. "The Psychic Factor as an Element in Temperature Disturbance" is also well brought out in an article so entitled by F. B. Wynn.† Dr. Abt in discussing an increase of temperature in apparently normal children further emphasizes the fact that neurotic children, those convalescing from acute infection and tonsillar hypertrophy, older, delicate children undergoing athletic training or hurried dressing, and children who are poorly nourished or anemic may present variations of temperature above normal. Carious teeth and osteoclasia, obscure inflammation of the middle ear or tonsils, may give rise to it. Leucocytosis, though of mild degree, may be a signpost of importance and assist in determining the significance of small degrees of temperature.‡

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* Temperature Variations in Infancy and Early Childhood, Ill. Med. Jour., xxxvi, No. 11 (July, 1919).

† Jour. A. M. A., lxxiii, No. 1 (July 5, 1919).

‡ Copeland, E. P., Fever of Obscure Causation in Infancy and Early Childhood, Jour. A. M. A., lxvii, No. 19 (Nov. 4, 1916), p. 1346.

In re-admitting children who have been absent from school a rise of temperature should be considered as perhaps indicating the onset of infectious disease; without other indications it may be disregarded usually, unless there is either a history or clinical evidence of trouble. Certainly many children who have run to school, or are excited on their return after absence, show a rise of from one-half to two degrees of temperature without any other indication of disturbance.

In the author's experience at the School of Education, Chicago, it proved to be wiser to retain children for an hour or less in the office if upon return to school they were found to have a rise of temperature. The temperature became normal in the majority of cases within an hour after the hurry and excitement of readmission had passed.

CARRIERS

A carrier is an individual who harbors communicable bacteria without presenting symptoms.

Ludvig Hektoen* explains the carrier phenomenon as follows: "Since the discovery of the microbe carrier the adaptation of microbes to the defensive mechanisms of the animal body acquires new interest. Under the conception that phagocytosis and bacteriolysis form the basis of healing and immunity in many infectious diseases, the infecting microbes should disappear at the time of recovery; this is probably the general rule, but there are many exceptions, illustrated by the now familiar "bacillus carrier." The body may overcome the disease but not the cause, which may persist in spite of the increase in antibodies; the disease subsides, the disturbances are smoothed away, and yet the germ lives on in the host, apparently harmless and unharmed, sometimes for remarkably long periods. But the equilibrium is not always a stable one; the immunity of the host may give way and recurrence develop; or the resistance of the germ may weaken and eventually complete destruction, and final elimination take place. Germs isolated from typhoid and cholera carriers have been found in some cases to offer special resistance to antibodies, including opsonins, but the mechanisms of this mutual immunization of microbe and host are still obscure."

Hektoen further explains the phenomenon of the carrier by two facts: first, that surviving microbes continue their existence in body cavities which are difficult to reach either internally or by local application. For example: typhoid fever carriers usually owe their persistence to the fact that these microbes are harbored in the cavity of the gall-bladder. As they do not penetrate the cells of the mucous membrane or any other tissues, they are practically without the body; at least they are not in a position to be attacked by drugs or serums. Second, in some instances, bacteria that have set up defensive reactions in the form of antibodies, themselves in time develop an immunity against these antibodies; for instance: some strains of typhoid bacilli are non-agglutinable early in the disease, but afterward when they have been taken from the body they become agglutinable.

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* Musser and Kelly, "Practical Treatment," i.

Carriers may be classified as follows:*

1. Primary or contact carriers. (*A*) transient; (*B*) chronic.
2. Secondary or convalescent carriers.
3. Contacts of contact carriers.

A primary carrier is one who has never had clinical manifestations of the disease in question. If *transient*, the bacteria have only a temporary hold; if *chronic*, cultures may be obtained indefinitely. The streptococcus hemolyticus is found in more than 50 per cent. of normal throats; the pneumococcus in 25 per cent.; the meningococcus in 1 to 13 per cent. with an average of 3 per cent. and the Klebs-Löffler in 1.4 per cent.† Some germs are found intermittently; in this type there may be a series of negative cultures followed by a positive culture. The primary carrier greatly out-numbers any other type.

The secondary carrier is one who, having recovered from clinical manifestations of the disease continues to harbor the germs that have produced it. Probably a great many cases which are apparently contact carriers are in reality convalescent carriers whose symptoms have been too slight for recognition.

Carrier foci may be found either in the respiratory or the alimentary tracts. In the respiratory tract are found streptococcus hemolyticus producing septic sore throat and streptococcus pneumonia, the pneumococcus, the Klebs-Löffler bacillus, bacteria causing influenza, the organism causing poliomyelitis, that producing epidemic encephalitis and the meningococcus. In the alimentary tract are found the typhoid bacillus and the organisms of dysentery.

The Klebs-Löffler bacillus is found most frequently in the tonsils, less frequently in the nose alone, and least frequently in both the tonsils and nose. The streptococcus hemolyticus and the pneumococcus are also found most commonly in the tonsils. The meningococcus and the bacteria of poliomyelitis find their habitat in the nasopharynx. Recent investigations point to occluded accessory sinuses as being important foci of meningococcus carriers; adenoids, deformity and thickening of the nasal septum and ethmoidal cells are also predisposing factors.‡ A recent report of Dr. Simon Flexner|| points to the occurrence of several types of meningococci differing in virulence. He regards the number of bacilli harbored and their virulence as determining factors in deciding the degree of menace to their host, and says that when cases of meningitis are infrequent, healthy carriers tend to harbor not the highly parasitic but the less pathogenic varieties. Once cases become frequent, however, the number of healthy carriers of the

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* Keefer, Friedberg and Aronson, A Study of Diphtheria Carriers in a Military Camp, Jour. A. M. A., lxxi, No. 15 (Oct. 12, 1918).

† Simmons and Taylor, Bacterial Carriers in the Upper Respiratory Tract, Jour. A. M. A., lxxii, No. 26 (June 28, 1919).

‡ Clemenson, F. J., Naso-pharyngeal Conditions in Meningococcus Carriers, British Med. Jour. (July 20, 1918), p. 51.

|| Control of Meningitis, Jour. A. M. A., lxxi, No. 8 (Aug. 24, 1918).

parasitic or dangerous kind rises. This is true of the majority of infections that are capable of becoming pandemic.

"Poliomyelitis and pandemic influenza are examples of the potentiality of the carrier. Both of these diseases spread with the rapidity of local transportation facilities, both are for the greater part of the time endemic and in a quiescent state and perpetuated only because there are carriers. The early cases of most epidemics are mild and unnoticed, increasing in virulence as they are transferred from person to person. It is necessary, therefore, not only to isolate the known cases, but to discover the unknown. If we recall the assertion that there are 10 carriers to every patient, and that carriers beget carriers, it must be manifest that some uniform legislation regarding the latter is highly essential, if substantial prophylactic progress is to be made." Dr. Simon Flexner* cites the remarkable disappearance of Yellow Fever as an instance of what may be done in stamping out communicable diseases under government auspices, and suggests that the endemic focus of poliomyelitis in northwestern Europe and the endemic home of influenza between Russia and Turkestan may be eradicated by attacking them also at their source, thus insuring universal protection from these overwhelmingly disastrous diseases.†

Streptococcus Carriers.—It has long been known that the streptococcus viridans occurs universally on the surface of the tonsils. More recent investigations show that both normal and diseased tonsils present the streptococcus hemolyticus in the crypts, and that no other part of the body harbors them so constantly. Moreover it is very evident that their location as centers of distribution is unrivalled. As these organisms do not apparently differ from the strains that cause such serious infections as the pneumonias, etc., the importance of the tonsils and the importance of the parasitic varieties of the streptococcus as carriers can not be over-emphasized.

Pilot‡ found that in a "series of 24 persons with apparently normal throats, cultures from the throat and pharynx yielded hemolytic streptococci in 58 per cent. In 19 persons without tonsils, cultures similarly made gave positive results in 15 per cent., and in these persons were found either bad teeth or tonsil remnants." He also examined 100 hypertrophied tonsils which had been extirpated, and found the streptococcus hemolyticus on the surface in 61 per cent. In the same throats from which these tonsils were removed, cultures taken just before extirpation yielded 43 per cent. positives. Crypt cultures yielded 97 per cent. positives, and in almost all, the hemolytic variety was greatly predominant. Nichols and Bryan‖ made a careful study of tonsils that were removed from army recruits, and found that of

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* Epidemiology and Recent Epidemics, Jour. A. M. A., lxxiii, No. 13 (Sept. 27, 1919).

† Rose: Wickliffe. "Epidemic Control in Europe and the League of Nations." Review of Reviews. July, 1922.

‡ Davis, D. J., The Tonsil in Relation to Infectious Processes, Jour. A. M. A., lxxiv, No. 5 (Jan. 31, 1920), p. 317.

‖ Nichols, H. J. and Bryan, J. H. The Tonsils as Foci of Infection in Streptococcus Hemolyticus Carriers, Jour. A. M. A., lxxi, No. 22 (Nov. 16, 1918), p. 1813.

100 excised tonsils, 75 harbored the streptococcus hemolyticus. Their studies showed that no case of a carrier occurred among men who had had their tonsils properly removed. A very recent study by Van Dyke* shows that even in a series of tonsillectomized throats 16.4 per cent. presented markedly hemolytic streptococci and 29 per cent. a less markedly hemolytic streptococcus, resembling Brown's alpha prime type. Other studies† have shown that there is a nasal type of streptococcus infection that is prolific in producing secondary cases. It should be emphasized further that acute infectious diseases, especially measles and influenza, open the way for the activity of streptococci and increase their virulence, "reaching a point ultimately at which the small doses contained in infected droplets are sufficient to transmit the disease to a normal person. Thus a secondary invader with potentiality as a carrier may become transformed into a dangerous primary infective agent."‡

Simon|| quotes a study made at Fort Sam Houston in army measles wards, in which patients entering showed 11.4 per cent. streptococci. After three to five days the number increased to 38.6 per cent. after 8 to 16 days 56.8 per cent. To ascertain whether men who came to the hospital already infected with hemolytic streptococci had acquired these in camp or before, throat swabs were taken in 489 recruits, both rural and urban, as they stepped from the train. 14.8 per cent. showed hemolytic organisms.

The lesson to be learned from these facts is that a great majority of people in crowded quarters, as in the army or in schools, become infected through a relatively small percentage of supposedly healthy carriers. Of the infected in turn a certain number become ill, while still others join the ranks as new carriers. It is evident that hemolytic streptococci are constantly found in the crypts of all tonsils, both normal and diseased, and in a surprising number of thoroughly tonsillectomized throats, and must, therefore, exist in a latent state, except in sporadic cases and in epidemics of colds, sore throats, measles, influenza, etc., when they become virulent. Nichols and Bryan** made an unsuccessful effort to eliminate streptococcus carriers by the use of dichloramin-T, Dobell's solution and hot alcohol, as an application to the throat. They also tried 25 per cent. silver nitrate; this was more effective, but in some of these cases the crypt cultures were still positive after negative throat cultures. In order to test the disinfecting power of silver nitrate, several excised streptococcus tonsils were submerged in 25 per cent. silver nitrate for five minutes. They were then washed in salt solution and incised, and cultures were made from the crypts. All these cultures were positive. In cases with a few

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* Van Dyke, H. B., Hemolytic Streptococci in the Normal Throat after Tonsillectomy, Jour. A. M. A., lxxiv, No. 7 (Feb. 14, 1920), p. 448.

† Lewis, D. M., Streptococcal Infection Simulating Diphtheria, Boston Medical and Surgical Journal, clxxiv, No. 23 (June 8, 1916), p. 837.

‡ Davis, D. J.

|| "Human Infection Carriers."

** Ibid.

open crypts the silver nitrate may be effective, but in most tonsils it is impossible to sterilize the crypts by these means. They therefore urge the removal of tonsils that persistently harbor the streptococcus some weeks after the attack.

Pneumonia Carriers.—Dochez and Gillespie, and more recently Spooner,* found that Pneumococci I and II are never found in normal mouths. They are always truly parasitic. In the absence of contact with pneumonia cases, they are sometimes found in crypts, in nooks, and about other lymphatic structures of the throat, and they probably occur in the sinuses of diseased teeth. Hence, they may be found in the nasal secretion and sputum of such persons when they have ordinary colds. They are not infrequently present in the mouths of person who have been in contact with pneumonia patients, and are often found to persist for some time during and after convalescence. There can be no question that the diseased or convalescent carrier is far more of a menace than the contact carrier.

Type III occurs in a large percentage of healthy persons who have not been in contact with corresponding active cases—and it has the highest death rate. Type IV is found in from 50 to 80 per cent. of normal mouths, so that there may be some hesitation in calling harborers of this type "carriers."

Stillman found carriers of the various types of the pneumococcus distributed among 942 normals as follows:

TABLE 7

	No. of cases	Percentage
Type I	34	7.0
Type II	22	4.5
Type II*a*	1	0.2
Type II*b*	26	5.3
Type II*x*	47	9.7
Type III	85	17.5
Type IV	271	55.8

I, II, and III produce 80 per cent. of all the pneumonias; type IV produces 20 per cent.

A good mouth wash and gargle for pneumonia carriers is the following:

℞.	Ethyl hydrocuprein hydrochloride or quinine bisulphate	0.005
	Liquor thymolis	5.0
	Aqua distillata	āā 50.0

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* Spooner, Lesley H., Acute Respiratory Carriers, Jour. A. M. A., lxxiv, No. 9, (Feb. 28, 1920), p. 582.

The liquor thymolis used in this prescription has the following composition:

℞.	Benzoic acid	gr. 64
	Boric acid	gr. 128
	Thymol	
	Menthol	āā gr. 16
	Oil eucalyptus	
	Oil wintergreen	
	Oil monarda	āā oz. iv
	Aquæ	q. s. ad. oz. xvi

A similar solution may be made up in undiluted Dobell's Solution to use as a spray for the nose and throat. It may also be incorporated in a dental cream and used for cleansing the teeth. (Human Infection Carriers. Simon.)*

If the sinuses are involved or the pneumococcus persists in the tonsillar crypts, tonsillar enucleation should be considered, and every effort made to cure the sinus condition.

Diphtheria Carriers.—Numerous studies have been made of the persistence of infection following diphtheria. Tjaden† examined 1338 cases repeatedly till the bacilli were gone. His report is as follows:

Table 8

In 897 cases (67.0 per cent.) the organisms were gone after 2 weeks.
In 1004 cases (75.0 per cent.) the organisms were gone after 3 weeks.
In 1109 cases (83.6 per cent.) the organisms were gone after 4 weeks.
In 1192 cases (89.1 per cent.) the organisms were gone after 5 weeks.
In 1248 cases (93.4 per cent.) the organisms were gone after 6 weeks.
In 1297 cases (96.9 per cent.) the organisms were gone after 7 weeks.
In 1303 cases (97.4 per cent.) the organisms were gone after 8 weeks.
In 1329 cases (99.3 per cent.) the organisms were gone after 9 weeks.
In 1331 cases (99.5 per cent.) the organisms were gone after 10 weeks.
In 1336 cases (99.9 per cent.) the organisms were gone after 11 weeks.
In 1337 cases (99.95 per cent.) the organisms were gone after 14 weeks.
In 1338 cases (100.0 per cent.) the organisms were gone after 17 weeks.

Park estimates that virulent bacilli are present in probably 1 per cent. of all healthy throats in New York City. Paul Sommerfeld‡ found bacilli in eight children out of 368 or 2.1 per cent. in a general hospital in Berlin. Graham Smith|| has tabulated the results of many observers on the infection of healthy contacts with diphtheria bacilli. His statistics show that of close contacts, *i.e.*, members of infected

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* Levy, R. L., and Alexander, H. L., Results of the Separation of Carriers from Non-carriers at a Base Hospital, Jour. A. M. A., lxx (1918), p. 1827.

† Deutsch Arch. f. Klin. Med., lxxxix (1906), p. 292.

‡ Zur Epidemiologic d. Diphtherie, Arch. f. Kinderheilk, xlvii (1911).

|| "The Bacteriology of Diphtheria" (1908), p. 186.

families, relatives and attendants, 36.6 per cent. are liable; and among scholars of infected schools 8.7 per cent. In the general population Goldberger, Williams and Hachtel* found that 0.928 per cent. harbored bacilli that were morphologically diphtheritic. Diphtheria bacilli from patients with diphtheria, and from carriers who have been in contact with such patients, are practically always virulent. The bacilli in such cases usually remain virulent up to the time of disappearance, even though a long time has elapsed.†

Diagnosis.—The material should be obtained from the tonsillar crypts, and from both the anterior and posterior aspects of the nose, and cultures should be taken from every case of middle ear disease. That it is important to culture the nose is shown in an army investigation of diphtheria: 700 cultures were made from the nose and throat, 26 per cent. of which gave positive returns from the nose and 31.7 per cent. from the throat. The efficiency of the tonsil as a harbor of chronic infection is determined by its condition rather than by its size. "The degree to which the tonsil is covered, the extent of surface exposed, lobulation, and the presence of folds or crevices, all have a definite influence by interfering with the evacuation of crypts." The Schick test is usually negative in diphtheria carriers.

Quarantine of Diphtheria Carriers.—Persons known to be diphtheria carriers should be placed in quarantine and isolated. Children of the family who yield negative cultures, and do not come in contact with the carrier in any way, need not be excluded from the schools. Contacts should be quarantined for one week unless immunity has been proven by a negative Schick test or complete immunity has been secured by toxin-antitoxin three months previous to exposure or cultures obtained from throat and nose are negative.

Treatment.—As local applications are generally inefficient, and the use of antitoxin is absolutely without effect, it is important to remove infected tonsils as soon as the condition as carriers is recognized. This can be done as early as the end of the third week after the beginning of diphtheria. It is also necessary to remove pathological conditions of the nose, nasopharnyx and sinuses. If removal can not be secured, the following methods of treatment are reported as of value: Chloramin-T., 0. 25 per cent. aqueous solution used as a gargle three or four times daily, followed by an oily spray of dichloramin-T of 2 per cent. strength,‡ or the following method reported by M. Esther Harding, British Medical Journal Jan. 5, 1918. "Sterilization of the Throat after Diphtheria and in Carrier Cases." The child wrapped in a sheet is laid across the bed with the head in the operator's lap. This prevents an excess of the solution running down the throat, thus avoiding spasm of the glottis; 30 to 40 minims of silver nitrate solution 12.5 to 25 per cent. is applied with long sinus forceps and absorbent cotton. Of cases with positive cultures, 70 per cent. were rendered sterile with the first application, and 20 per cent. by a second painting with a 25 per cent. solution; the remaining 10 per cent. required several other applications.

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* Bulletin 101, Hygiene Laboratory, Washington, D. C., p. 29.

† Weaver G. H., The Virulence of Diphtheria Patients and Diphtheria Carriers, Journal of Infect. Diseases, xx (Feb., 1917), p. 129.

‡ McCord, Friedlander and Walker, Diphtheria and Diphtheria Carriers in Army Camps, Jour. Am. Med. Assn., lxxi (1918), p. 275.

Influenza Carriers.—Carriers of Bacillus Influenzæ are both active and passive. Tubercular patients occasionally are found who have had influenza and have harbored the bacillus of Pfeiffer for years. It frequently is found during investigations of whooping cough, diphtheria, measles, scarlet fever, and chronic bronchitis.* Schiller., R† states that 24 per cent. of healthy individuals harbor B. influenzæ in the nasopharynx.

The habitat of this organism is the pharyngeal tonsil. Carriers in ordinary years seem to be innocuous. This may be due to immunity acquired during previous epidemics, or to the loss of virulence by continued animal passage.‡

The viability of B. influenzæ is slight outside the human body, if it is dry. In presence of moisture, however, organisms are infectious for two weeks.

For culture methods see Simon—"Human Infection Carriers," p. 207.

Management of Carriers.—Instruct the public, wear masks, isolate promptly.

Poliomyelitis Carriers.—The infectious virus found in the secretions of poliomyelitis resists drying. It has even been known to persist for two years after an attack. It has been shown also|| that the well members of a patient's family may carry the virus, paralysis having been produced in monkeys by inoculation with nasopharyngeal secretion from such persons. Abortive cases are doubtless responsible for from 25 to 50 per cent. of the entire incidence.** While the number of carriers far outdistances the number of sick patients, it is nevertheless unusual for a carrier state to be developed. "The fact that even after a severe and wide spread epidemic, such as occurred in the United States in 1916, the disease may virtually disappear within two or three years, points to the probability that enduring carriers

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* Editorial, Jour. A. M. A., lxxi, No. 14 (Oct. 5, 1918), p. 1138.

† Ueber d. Verbreitung d. Influenza bacillen eine epidemio logische Studie, Centralblatt f. Bakt. Abth I, i (1909), Die Gruppe d. hemoglobinophilen Bakterien, Handbuch d. pathogenen Micro-organismen von Kolle u. Wassermann, idem, v, 2 ed., p. 1257.

‡ Simon, "Human Infection Carriers," p. 206.

|| Taylor, E., and Amoss, H. L., Carriage of the Virus of Poliomyelitis with Subsequent Development of the Infection, Jour. Exp. Med., xxvi (1917), p. 745.

** Taylor and Amoss., ibid., and Flexner, S., Clark, P. F. and Fraser, F. R., Passive Human Carriage of the Virus of Poliomyelitis, Jour. A. M. A., lx (1913), p. 201.

of the active virus, whether healthy or chronic, are of exceptional occurrence."*

There must be quarantine, preferably hospitalization for all carriers. If hospitalization can not be obtained, the patient must be strictly isolated with a nurse; if isolation is not possible, there shall be rigid quarantine of the family. The duration of quarantine is at least three weeks. The removal of tonsils will facilitate recovery from the carrier state.

Meningococcus Carriers.—Only a very small per cent. of persons who have had meningitis harbor the organism long enough to be classed as carriers. The meningococcus disappears from the nasopharynx and the tonsillar ring of patients, usually within three weeks after the onset of the disease. On the other hand, at least 50 per cent. of the immediate contacts serve as hosts for the organism, and it is through such contacts, and their contacts, that the disease is spread. The following table shows the findings obtained by Flach in 185 carriers.†

Table 9

	Contact carriers	Per cent.	Non-contact carriers	Per cent.
Under 2 weeks	20	16.20	12	19.67
2– 4 weeks	45	36.29	32	52.46
4– 6 weeks	26	20.97	5	8.19
6– 8 weeks	14	11.29	2	3.28
8–10 weeks	4	3.23	7	11.48
10–12 weeks	5	4.03		
Over 12 weeks	10	8.07	3	4.92
		100.00		99.99

It appears, therefore, that the duration of the disease on the whole does not differ between contact and non-contact carriers. The duration of the carrier state depends somewhat upon the extent of distribution of the meningococcus in the upper respiratory tract. The degree of danger to others depends upon the number of organisms, the amount and severity of coughing and sneezing, the intimacy of contact dependent upon the size of the rooms and ventilation and upon the susceptibility of people with whom the patient is associated. Children, young adults, and people from the rural districts are in particular danger. "As the number of carriers produced exceeds the number of cases of infection arising 10 to 20 times, we may infer that individual susceptibility to epidemic meningitis is low."*

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* Flexner and Amoss, Persistence of the Virus of Poliomyelitis in the Nasopharynx, Jour. of Exp. Medicine, xxix (1919).

† Flach, M., and Gordon, M. H., "Bacteriological Studies in the Pathology and Preventive Control of Cerebrospinal Fever Among the British Forces, 1915 and 1916," Published by the Medical Research Committee, London, Special Report Series (1917), No. 3.

An excellent form of treatment for meningitis carriers is outlined by Dunham and Dakin,†

> ℞. Clear the nose with salt solution, or 0.25 per cent. aqueous chloramin-T solution, either by spraying or irrigation. The nose should be blown into a handkerchief between applications, and the chloramin-T solution should also be used thoroughly as a gargle.

After the increased flow of nasal secretion has subsided, the oil solution of dichloramin T is applied with an oil atomizer. The oil spray should be applied every four hours in the day time. There may be considerable sneezing at first, but this soon subsides.

In the United States there are different methods of handling the carrier situation in meningitis, varying with the efficiency of the organization of the States. Missouri, for instance, has no statutory authority in the case of communicable diseases, while New York is ably organized.‡ The law in New York State‖ does not regard three consecutive negative cultures taken at three-day intervals as insuring permanent freedom of a carrier from the meningococcus. At least five successive cultures should be required, and the carrier cultured at intervals after release. Carriers are excluded from all public assemblies. **

If it is necessary to make a bacteriological investigation of the carrier situation, swab first the close associates of the case, extending and widening the circle according to circumstances if more cases arise.††

Carriers of the Alimentary Tract. Typhoid Fever Carriers.—Following an attack of typhoid fever, the bacillus of Eberth may persist and multiply in the gall-bladder, the urinary bladder, or an abscess which has access to the intestinal or the genito-urinary tract.

The Widal test is available as an aid in the discovery of typhoid carriers. Widal tests giving a positive result indicate the presence of typhoid infection. If the presence of typhoid fever is indicated, the stools and urine should be examined until five successive examinations at intervals of three days have negative results. In doubtful cases it is well to administer three to five grains of inspissated ox bile daily for several days, followed by a mild laxative. This should immediately precede the collection of the fecal sample. The urine should be examined at the same time, even though it be clear. All those engaged in the lunch-room service, or otherwise engaged in handling food, should be subject to Widal tests and to an examination of the excreta. There are probably 25,000 typhoid carriers living in New York City. In some districts passive carriers of paratyphoid are so common that it is exceptional to meet individuals who are not carriers.* It is very difficult, therefore, to cope with the problem efficiently. Important steps are the following:

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* Flexner, S., "Mode of Infection, Means of Prevention, and Specific Treatment of Epidemic Meningitis," The Rockefeller Institute for Medical Research (1917).

† British Medical Journal, i (1917), p. 682.

‡ The Carrier Problem in Meningitis, Editorial, Jour. A. M. A., lxxiii, No. 9 (Aug. 30, 1919).

‖ "Public Health Manual," New York State, Dept. of Health (Feb. 1, 1919).

** Robey, William H., and Saylor, Howard L., Clinical and Epidemiological Studies on Epidemic Meningitis, Jour. Infect. Dis., xxiii (Oct., 1918), p. 317.

†† Flexner, S., in Discussion of An Experimental Study of Parotitis, Martha Wollstein, Jour. A. M. A., lxxi, No. 8, p. 644.

1. The registration of every carrier;
2. Information of change of residence;
3. Prophylactic vaccination of all those thrown in contact with the carrier;
4. Administration of hexamethylene tetramin (urotropin) in large doses (75 gm. per diem with 10 to 30 grains of benzoic acid to maintain the urine in an acid state in those cases where the urinary bladder is involved). In very obstinate cases it may be desirable to perform a cholecystectomy.

If a carrier is allowed to live in an unsewered district the excreta should be sterilized, and the use of a fly-proof sanitary privy should be installed. The contents of the privy vault must be disinfected with lime or other disinfectant at stated intervals under the direction of the local health officer. There should be frequent thorough scrubbing of the interior of the privy, the carrier should scrub his hands thoroughly after defecation and micturition, and before handling table dishes, food, etc. His bed and personal linen should also be disinfected.†

Dysentery Carriers.—Dysentery is a filth disease caused usually by two pathological organisms: The bacillus dysenteriæ of Shiga and the entameba histolytica. The lamblia intestinalis and other types of dysentery bacilli are associated with dysentery, but are not pathogenic. These organisms are found in great numbers at the beginning of the disease, especially where there is poverty, disorder and uncleanliness. In such cases all the members of a family have it and become carriers throughout the neighborhood or in the school. There are very few passive carriers. Once having had the disease, recurrences are frequent. W. Kruse,‡ found a case in which the Shiga Kruse organism was present eight months after the attack. Flies also distribute the disease, especially where the sewage is inadequate.‖ Under such conditions as these the patient should be sent to a hospital.

Dysentery is by no means restricted to hot climates. A. H. Sanford,** found that of 1135 patients infected with the ameba histolytica, the pathogenic organism of dysentery, 535 were from the North and 600 from the South. It is said that sporadic cases occur in New England and exist sometimes for 20 years.

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* Simon, "Human Infection Carriers."

† Senftner, H. F., A Typhoid Carrier Problem, Jour. A. M. A., lxviii (June 23, 1917), p. 1873.

‡ Die Verbreitung der Rhur durch sogenannte Dauer-Ausscheider und Bacillenträger, Klin. Jahrb, xix (1908), p. 529.

‖ Hurst, A. F., Dysentery, Guy's Hospital Gazette, xxxi (June 30, 1917), p. 243.

** The Geographic Distribution of Amebiasis, Jour. A. M. A., lxvii, No. 26 (Dec. 29, 1916), p. 1293.

The typical symptoms of dysentery in carriers are diarrhea and tenesmus with the passage of blood and mucus.* Sometimes, however, carriers do not have diarrheal symptoms. Sanford found that 41 per cent. have constant diarrhea, 33 per cent. intermittent diarrhea often alternating with periods of constipation, and that 26 per cent. have had no bowel trouble at all, except constipation. Usually there are no ulcerations in patients from the North, and frequently there is no fever. These facts indicate the difficulty of placing the source of infection when an epidemic occurs.

For a diagnosis of the organism see "Method for the Isolation and Rapid Identification of Dysenteric Bacilli," Klighe & Olitsky, Jour. A. M. A., lxxi, No. 26 (Dec. 28, 1919), p. 2126.

Management of Dysentery Carriers.—As long as mucus appears in the stools following an attack of dysentery the case should be regarded as a carrier. Carriers should not handle food, they should use separate utensils for eating and drinking, which should be sterilized after being used, and their excreta, personal and bed linen should be sterilized. The privy should be screened. While actual quarantine is seldom necessary, the health department should be notified.

MEDICAL INSPECTION

Preceding the opening of schools following the summer vacation it is customary for departments controlling school health to hold preliminary meeting for instruction of medical inspectors and standardization of the work. This work includes:

1. A preliminary determination of summer exposures to communicable diseases, especially in epidemics of poliomyelitis.
2. Preliminary room medical inspection of pupils.
3. Daily school visits of medical inspector, nurse, school hygienist, dentist, or nutrition worker.
4. Physical examinations.
5. Follow-up work.
6. Treatment.
7. Social work.
8. Education of pupils and parents in hygiene.

In case of a generalized severe type of infection, such as infantile paralysis, certificates from health officers in localities where the pupils have spent the summer, and also from their local physicians in the city, are required. These are sent to the medical office of the school some days in advance, and checked up with lists of pupils by rooms or grades. Lists of names of children in the grade who have not met this requirement fully are then sent to the teacher of the room or grade,

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* Kennedy and Rosewarm, Observations upon Dysentery Carriers, British Medical Journal, ii (Dec. 23, 1916), p. 864.

THE UNIVERSITY OF CHICAGO
THE SCHOOL OF EDUCATION
THE UNIVERSITY HIGH SCHOOL

ATTENDANCE CARD

Pupil's names	Month of January																									Attend.	
	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	Absence	
1917 Date		2	3	4	5	8	9	10	11	12	15	16	17	18	19	22	23	24	25	26	29	30	31				
White, Mary....		cold	cold	cold	home	✓								not ill	✓												1–5, Throat congested, temp. 99.8, not admitted. 1–18. Went down town.
Drane. Doris....			grippe	grippe	grippe	grippe	✓								ill	✓											
Green, Gladys...				headache	✓				precaution	precaution	precaution	precaution	precaution	precaution	precaution	✓											1–11, Fear of contagion, in a weak condition.
Jones, Bertha....					throat	throat	home	home	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever	scarlet fever				1–9, Not admitted, sore throat, temp.
Black, Bernice...									cold	cold	cold	cold	cold	cold	cold	✓											1–12, Returned home, S. F. contact.
Mason, Marion..					headache	✓						teeth	✓			earache	✓		eyes	eyes	✓						1–25, Broke glasses, eyes weak.

Howell, Louise...								inj. back	inj. back	inj. back	✓																1–10, Fell at noon, hurt back, returned home.
Golden, Gloria...			pain in side	pain in side	appendicitis	appendicitis	appendicitis	appendicitis	appendicitis	appendicitis	✓																1–15, No gym. for one year on account of operation.
Spencer, Lillie...					cough	cough	✓				vaccinated	vaccinated	vaccinated	✓													1–15, Typical result, certificate OK.
Dobbs, Grace...								out city	out city	out city	✓			tired	✓			aunt ill	aunt ill	aunt died	aunt died	✓					
Bardwell, Pearl..					rheumatism	rheumatism	rheumatism	✓					tonsillitis	tonsillitis	tonsillitis	✓		tonsils out	tonsils out	tonsils out	✓						

CHART 3.

who sends to the office such children as they arrive. These children are excluded until the required certificates are presented. .

At present, routine inspection is made of all school children during the first four days of each term. As the medical officer visits the school rooms for a cursory and rapid examination of the pupils, he places himself near a window, with his back toward the light, and in such a position that the children can easily file by him. As they pass in a continuous column, each child extends and turns his hands, and opens his mouth in order that a tongue depressor may present a good view of the throat for inspection. It is needless to say that a fresh depressor is used in each case. The eyelids are then pulled down, and girls raise their back hair. Throughout the examination the inspector aims to avoid physical contact with the pupils. The teacher stands near the examiner and records all physical defects on index cards, which are kept for reference. Children with communicable diseases are referred to the principal and sent home with a printed form, which states the main facts concerning the type of disease from which the pupil suffers and a notice that further inspection will be made in the home by a city medical official. The names of all children otherwise requiring treatment are recorded and referred to the school nurse.

Daily Inspection.—Each morning before 10 o'clock, if possible, each room is visited by the school nurse. She confers with the teacher and walks through the aisles inspecting the pupils. All suspicious cases, and all those who upon such superficial examination seem to be in need of medical care, are sent at once to the medical office to be examined more carefully by the medical inspector. If the number of children is too large for room inspection, all children suspected by the teacher of having a communicable disease, or otherwise needing medical care, are sent to the nurse's office. All pupils having sore throat are cultured and sent home, and children with evident communicable disease are referred to the medical inspector for further examination or sent home.

School Absentees of four days or longer standing are required in many cities to visit the medical inspector or the nurse before reinstatement, and for this purpose should go directly to the office before going to their rooms. The medical inspector may lawfully re-admit all cases recovered from infectious disease except smallpox, scarlet fever, and diphtheria. In the City of New York the names and addresses of children recommended for exclusion are telephoned to the borough office of the division together with a tentative diagnosis. Temperatures are taken (see paragraph on Temperature) and the child otherwise carefully examined, and if found not suffering from contagious disease he is then given a certificate and allowed to return. If communicable disease exists, the case is quarantined (see paragraph on Communicable Diseases).

If contagious eye or skin disease is found, notice is sent to the parents to that effect with recommendation of treatment, and the child is told to report to the nurse the morning following. Upon inspection, if the nurse finds evidence of treatment, he is allowed to remain, appearing at regular intervals for further inspection to ensure continued treatment.

When no treatment has been obtained the method of procedure in New York is the following:

(*a*) Cases excluded:

1. Contagious eye diseases with symptoms of acute inflammation or discharge.
2. Contagious skin diseases with extensive lesions.
3. Pediculosis with live pediculi.

(*b*) Cases allowed to attend school while under treatment by a private physician, dispensary, or the school nurse:

1. Acute conjunctivitis.
2. Pediculosis (with no live pediculi).
3. Skin diseases, including ringworm of scalp, face or body; scabies, favus, impetigo, molluscum contagiosum.
4. Trachoma cases are instructed as to the necessity for treatment, and are required to report to the nurse at regular intervals for inspection, but are never treated by the nurse.

In private schools of the highest type the teachers send lists of *all* absentee pupils to the medical office each morning before 10 o'clock. As all the homes are provided with telephones it is possible within a short time for the office to ascertain the cause of absence. In rural communities, where the telephone is generally installed, the same method would be practicable, the teacher in such instances making a tentative diagnosis in place of the medical office. As early information in regard to communicable disease is most important in checking its spread, this function of the teacher is not only legitimate, but desirable. In the Ethical Culture School of New York City the causes of absence in each room are recorded daily upon a large sheet (Chart, pp. 912, 913) spaced for a daily record of three or six months. By means of this it is possible to obtain a rapid, correct impression of the individual record of each pupil, and also that which is much more valuable, an impression of the present condition of the health of the room as a whole. When colds are prevalent, the sheet sometimes reveals the fact that almost the entire room population has been affected. This is invaluable in knowing how to handle the problem discreetly.

If the medical office of private schools desires it, they may obtain from the Department of Health a list of the names and addresses of all new cases of communicable disease in the city. With this information and a map, an interesting pin map may be made, especially relating to the district in which the school is located. This is a source of great interest to the pupils, and is a graphic method of teaching community hygiene.

Monthly and Mid-term Examinations.—Once a month the school hygienist (see section on the Teeth) or nurse should visit each room to make an inspection similar to that made by the inspector during the first days of the term. If she finds cases requiring treatment, she pursues the method indicated. In the City of New York, early in the history of medical inspection when only ten nurses were employed, 57,655 children were excluded from school for contagious eye and skin diseases: in 1912 only 4716 children were excluded for these causes.

Once a term the medical inspector should visit each room to watch the reactions of pupils during recitation and study, and to confer with the teacher. Children who squint or hold their books improperly, who complain of headache, toothache or earache, who are mouth-breathers, who look anemic and poorly nourished, or who are nervous in their actions, should be noted and sent to the inspector later for further investigation. If possible, the medical inspector should occasionally attend teachers' meetings, at which time the health of the pupils should be discussed and the teachers instructed.

A comprehensive report of each day's work is sent to the central office by the medical inspector and the nurse within 12 hours. Reports are sent also to the principal and to teachers in case of contagion or of physical defects which require school coöperation.*

"Follow-up" Work.—Follow-up work is distinctly the function of the nurse. Before this phase of the work was organized the Department of School Hygiene of the City of New York brought about the treatment of only 6 per cent. of school children who were found to have defects. Three years after the work was organized, excluding the cases of defective primary teeth, 80 per cent. obtained the needed medical or surgical work. Without "follow-up" work the physical examination for defects is hardly justified, as it means the outlay of an enormous sum of money without results. At present, when any defect is found, the parent is notified by means of a special blank form, calling attention to the defect and stating that the child should be taken to the family physician for treatment. When no attention is paid to this notice, a follow-up notice to the same effect is sent the parents by the principal of the school. If the parents call at the school, the inspector or nurse explains the nature of the defect and the need of treatment; if they do not respond within three days, the nurse visits the house and explains to the parent the nature of the defect, the need of treatment, and the beneficial effects that may be reasonably expected to result from medical care. Repeated home visits are made by the nurse until treatment is provided, or an absolute refusal encountered. If parents are willing to have their children treated, but unable to pay, and if they are occupied so that they can not spare the time to obtain treatment, the nurse takes the child to a dispensary after the parent has signed a request to that effect. After the child has obtained treatment he is reëxamined by the medical inspector, who records the results.* Both the findings and the work of the inspector and the nurse are recorded on duplicate medical examination cards, one sent to the Department of Health and the other kept in the office of the principal. Every effort is made to coöperate with the principal and teachers and with the family physician.

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* See Rapeer, "School Health Administration," pp. 343–52; Hoag, "The Health Index of Children," Cornell, "Health and Medical Inspection of School Children;" Dressler, "School Hygiene."

Free Clinics.—Social problems enter constantly into health work. Nowhere is this more plainly seen than in the health work of the public schools. Society may be roughly divided into three classes for the purpose of consideration in this connection, *viz.*, the capitalist, the middle class. In the lower class there are many so deficient either mentally or physically, or both, that they require either public or private supervision. A study was made of public health efficiency in relation to the administration of the health work in the public schools of New York City by Dr. Lewinski-Corwin,† He selected four schools in the Borough of Manhattan. One was on the lower East Side in a section whose population is composed almost entirely of Russian, Austrian and other Jews, but where the coöperation of the school authorities with the health officers is known to be excellent. Another was a school having a mixed population—foreign to a great extent—where the interest of the principal in the work of the health department's officials was known to be slight. A third school, was also in a Jewish quarter but in another section of the city near a large and efficient dispensary and the fourth school was in a representative well-to-do district of the city. From these schools, out of 482 cases *which were treated,* 42.3 per cent. were cured, and another 20 per cent. improved. As the purpose of medical inspection in the schools is the remedy of defects, these results are very satisfactory.

It is usually thought that advantage is taken of dispensaries by those who can afford to employ physicians. The following table, compiled by Dr. Lewinski-Corwin shows this idea to be fallacious:

TABLE 10

School	Total number of cases treated	Treated by physicians	Treated in dispensaries
School A, lower East Side	104	47	56
School B, neighborhood of 30th St. and 2d Ave	88	41	45
School C, up-town well-to-do district	94	54	31
School D, upper East Side	196	93	96
Totals	482	235	228

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* Baker, S. Josephine, The Division of Child Hygiene of the Dept. of Health of the City of New York; and School Medical Inspection in New York City, Medical Record (Dec. 20, 1913).

† The Practical Necessity of School Clinics, The Popular Science Monthly (May, 1914).

Many dispensaries are now equipped with a social service department, a part of whose work is the investigation of the financial condition of its clientele. It is apparent from the table that people of all classes avail themselves of the dispensary. On the other hand, it is surprising that among the very poor so many should employ their own physicians. In relation to dental dispensaries these facts are even more remarkable, not more than 17 per cent. availing themselves of dental dispensaries.

Central Free Dispensary, connected with Rush Medical College, Chicago, and some others in different parts of the country, are adapting themselves to the convenience of working people—consequently early evening clinics are held, and hospital connections are established so that tonsillectomies and other minor operations, formerly undertaken in the dispensary proper with no little danger to the patients, can now be performed with hospital equipment followed by bed privileges and careful watching. The school clinic is meant to supply treatment for those whose parents are unable to afford or carry out the necessary treatment. Though people with means should always be encouraged to pay for the service they receive, the time will come when school clinics will be available to all tax-payers in the same sense that the public school itself is available. This advance will be reached when the public is awakened to the idea that the physical health of school children is as necessary as the education of their minds—perhaps more so. Already in New York City there are school clinics for nose and throat, for contagious eye diseases, and for the treatment of defective teeth. The school nurses or school hygienists care for minor skin diseases.

In order to procure school clinics it is necessary to educate the parents to their importance. In every town, public spirited physicians may be found who will volunteer to organize such work. After its value has been demonstrated, it is time to agitate the matter in Parent-Teacher Associations, with the Commissioner of Health and the Board of Education.

By coöperation with public or private charities and associations poor parents can be assisted in giving their children the needed attention.

Education of Parents.—Both medical inspectors and nurses have a very important function as health educators. Medical inspectors instruct the children and the parents of children, either at the time of the physical examination, or later when the parents respond to notification of the defects of their children. The medical inspector should seek the opportunity to address groups of parents or parent-teacher association meetings on matters pertaining to the health of school children. The nurses' opportunities in the school are with the individual child, or with groups of children, at the time of examination or treatment, and on all occasions when she visits the home. In some cities she conducts "Little Mothers' Classes or Clubs," and it is often desirable for her to address parent-teacher associations.

Material that will assist in the education of parents is found in (1) "Home Hygiene and the Prevention of Diseases"—Ditman, (2) Dental charts; (3) Health lectures; (4) Tuberculosis and other health exhibits; (5) Health budget exhibits for medical supervision; (6) Pamphlets on infant and child hygiene for parents; (7) Pamphlets on sex hygiene; (8) Newspapers; (9) Elsa Denison's book "Helping School Children;" (10) Annual health day, or health week in the schools.

AGE AND DEVELOPMENT IN RELATION TO SCHOOL ENTRANCE

It is the general consensus of opinion that for the average child six years is the best age for entering the elementary school. In Germany* children are not allowed to enter under the age of five years and nine months. Admission following Easter is only permitted in children whose birthdays will occur before July 1. Some authors† regard the physiologic age and the relation of the home to the school as of greater importance as determinants of school entrance than chronological age. If the home conditions are exceedingly poor, it may be an advantage to the child to attend school earlier. On the other hand, as there seems to be a correlation between physical and mental development, it is desirable either to hold back the poorly nourished, anemic, rachitic possibly tubercular child until he has had opportunity to develop, or else to place him in schools designed primarily for the purpose of promoting health (see Vorschule, p. 1122).

In discussing the problems of age for school entrance in children from homes of the well-to-do, G. S. Hall‡ says, "It is true that the school as it is now conducted takes the child from home and play too early, but the remedy for this is not to begin school later, but to change the methods. At present the first two years are likely to be nearly wasted, for the school takes the child at an age when there is often weakness and ill adjustment, shuts him up and away from nature and free social life, forces him to use only his small muscles, failing to see that all interests are now motor and demand free expression. All natural instincts should be given free and wide opportunity. The kindergarten ideals, rather than those of the higher grades, should dominate until the age of eight, and the time devoted to filling the mind and cultivating experience and expression."

There is no question but that home conditions, mental status, nationality, as well as food, have a bearing upon the physical characteristics of the child (see Nutrition).

Porter‖ examined 33,500 school children and found that those who belonged to the higher classes in school had better physical development than their older companions in lower classes. This was also found by Rietz in Bonn for district school children.

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* Kruse und Selter, "Gesundheitspflege des Kindes."

† Thiele, A., Versuch einer Biologie der Schulanfanger, Ztschr fur Schulgesundheitspflege, xxvi (1913), pp. 377–827.

‡ "Genetic Psychology."

‖ The Physical Basis of Precocity and Dullness, Transactions of the Academy of Science, St. Louis, Bd. vi, s. (1893), p. 161.

A table showing that the height of the children is less in direct proportion to their retardation:

TABLE 11

School year	1	2	3	4	5	6	7	8
				Boys				
	cm.							
Normal grade	112.7	118.5	123.3	128.1	132.9	137.9	142.1	147.0
Retarded 1 year	.....	115.7	121.4	125.8	131.8	136.1	140.0	144.2
Retarded 2 years	.....	.....	119.5	125.3	130.3	134.0	138.7	144.1
Retarded 3 years or more	.....	.....	.....	.....	.....	.....	137.9	143.3
				Girls				
Normal grade	112.3	118.1	123.1	127.9	133.6	139.7	144.4	150.0
Retarded 1 year	.....	115.3	120.6	126.0	130.9	135.5	142.0	147.4
Retarded 2 years	.....	.....	120.6	124.0	129.8	134.0	140.6	146.8
Retarded 3 years or more	.....	.....	.....	.....	.....	.....	140.0	144.0

A similar study of 42,000 school children in regard to the difference between city and rural schools reveals a difference in physical development as follows:

TABLE 12

School year	1	2	3	4	5	6	7	8
				Boys				
Age	6½	7½	8½	9½	10½	11½	12½	13½
	cm.							
City schools	117.4	123.4	128.0	132.6	135.0	139.8	145.6	150.0
District schools	112.7	118.5	123.3	128.1	132.9	137.9	142.1	147.0
				Girls				
City schools	116.2	121.8	127.1	131.8	136.0	142.5	148.4	153.7
District schools	112.3	118.1	123.1	129.9	133.6	139.7	144.4	150.0

Similar results were found in a study of the children in the Horace Mann, Francis W. Parker, and University of Chicago Elementary and High Schools* and in another study of the University of Chicago Elementary and High Schools.† The latter study showed that children of the University Elementary School (whose parentage was either of the faculty of the University or of the well-to-do of other professions or types of business) averaged 5 cm. more in height and 2.5 kg. more in weight than children of the public schools. Similar differences were also noted in grip, vital capacity, and head measurements. Binet tests showed also that the average mentality of this group was one year in advance of public school children. The truth of some of these statements and those related to nationality are shown in the accompanying charts.

* Baldwin, B. T., Physical Growth and School Progress, United States Bureau of Education, Bulletin No. 14 (1914).

† Young, Josephine E., Supernormal Environment and the Growing Child, Fourth International Congress of School Hygiene (1913).

All such facts as these should be taken under consideration by hygienists. Teachers should be informed of the relationship between the higher grades of physical equipment and mental progress, as well as the reason for the seeming indifference or laziness of many delicate children.

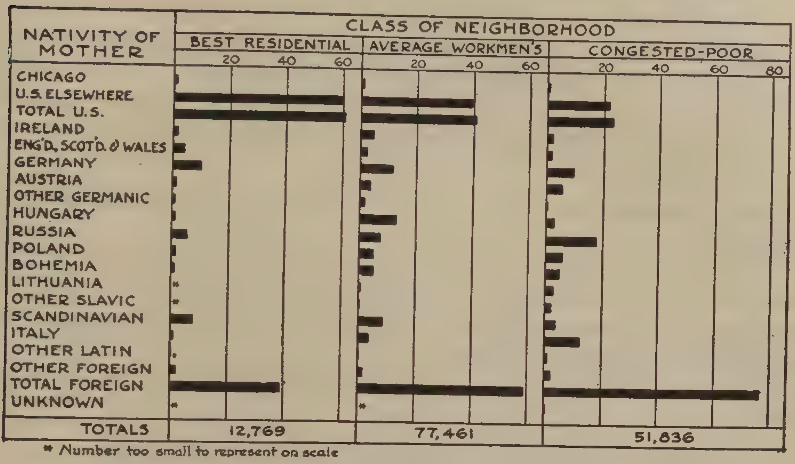

CHART 4.—Pupils examined physically classed by kind of residential districts and by nationality of mothers. Dep't. of Health, City of Chicago. Report for 1911–1918, p. 549.

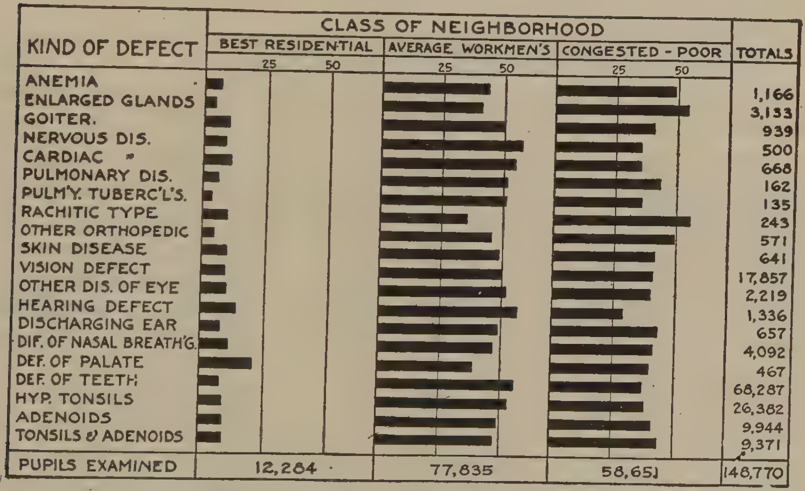

CHART 5.—Physical defects found classed by location of schools according to kind of residential district. Dep't. of Health, City of Chicago. Report for 1911–1918, p. 549.

W. H. Burnham* after discussing height, weight, head and chest circumferences, vital capacity, and grip, as given by Camerer, Monti, Lange, Gundobin and Steinhaus, advises the following measurements as minima for entering school children:

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* A Health Examination at School Entrance, Journal of the American Medical Association, Vol. lxviii, No. 12, p. 813.

1. The height should be at least 115 cm.
2. The weight should be at least 20 kg.
3. The chest circumference should be at least 53 cm.
4. Children on entering school should have all four of the six-year molars. This should be required of both sexes.
5. Standards should be the same at this age for boys and girls, although for girls a little less may be permitted regarding height and weight.

Bone development at this age, as shown by Roentgenograms* is as follows:

Times of Appearance of Epiphyses: Ulna—lower epiphysis, fifth to seventh year; phalanges (ossific center of second row) fourth to seventh year: all bones of the wrist are present, but only the os magnum and unciform are well developed.

By the end of the sixth year all epiphyseal centers have appeared except:

Humerus—lower epiphysis, trochlea, external epicondyle.
Ulna—upper epiphysis.
Femur—trochanter minor.
Completion of the obturator foramen.
Union of the ischium and ilium.
Ossification of the cartilage of the acetabulum.

For exhaustive Anthropometric Studies see Hrdlička, Ales., Anthropometry, American Journal of Anthropology, Vol. ii, Nos. 1, 2, 3, 4 and Vol. iii, No. 1.

The marvelous physical development of young children progresses without setback until the period between 7 and 10 years. Practically all tables of weight and height show a slight relative falling off at this time. With this occurs the second dentition with a concomitant loss of chewing surface and liability to toothache. There is also a change in the circulatory system. The heart becomes relatively smaller than the blood vessels, and there is a resulting tendency to heart weakness and fatigue.†

E. M. Hartwell's tables on the specific intensity of life show that in girls from the ages of eight to nine, and for boys from the ages of 9 to 10, there is a lessened rate of rapidity of increase in immunity. This period should be borne in mind in planning school curricula, as will be seen under the Hygiene of Instruction.‡

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* Rotch, "Living Anatomy and Pathology."

† Gundobin, "Besonderheiten des Kindesalters," p. 124.

‡ Physical Training, Its Function and Place in Education, American Physical Education Review, Vol. ii (1897), pp. 133–151. (See pages 407, 408 and 420.)

EXAMINATION FOR THE DETECTION OF NON-CONTAGIOUS PHYSICAL DEFECTS

Physical examinations may be conducted in two ways:

1. The customary public school method is the examination of an average of 10 children each day in a different school. In the City of New York all children entering school for the first time are examined as early as possible; thereafter special cases are examined who have been detected by the medical inspector, or referred by the school nurse, or teacher; finally the rest of the children are examined grade by grade. Every child should be weighed and measured at least at the beginning of each term, and every child should have a thorough physical examination at least once in two years. These examinations are made preferably by the medical inspector. If the community can not afford a medical inspector, an especially qualified nurse or school hygienist may conduct them.

2. In private schools and in those public schools of small communities that can afford it, it is desirable to make all physical examinations during the first two weeks of school before the strenuous activities of physical education begin. This entails an additional temporary force, and in most communities is not practicable. This method is very desirable, however, and if possible should be conducted along the following lines. Ten days before the opening of school, notices of the medical examination should be sent to the parents, making definite appointments and urging them to be present with their children. They are informed that the appointment may be changed if the one designated is inconvenient, providing it is requested before a date designated. In the case of new pupils a health blank is sent with the notification, which solicits information regarding the pupil's health condition during the preceding year and summer vacation, his past communicable, other serious disease and operation history, his present hygienic home conditions, including habits of sleeping, eating, out-door exercise, home study and routine, social and cultural activities not directly connected with the school, his vacation environment, and other miscellaneous information which may have a bearing on his health. These blanks are filled in by the parents and returned to the medical officer by each pupil as he comes for examination. They are kept on file in the health folders of the pupils.

The force required for the conduct of physical examinations is:

An office secretary.

Trained physical education workers.

- (*a*) Anthropometric measurements, which include nutrition estimates and observations.
- (*b*) Examination of postural defects and advice for corrective home work.

Physicians.

- (*a*) One who makes the tests for hemoglobin, examines eyes and ears, and takes temperature, pulse and blood pressure records.

(*b*) Two who complete the examinations of those pupils who are allotted to them. The examiners look at and record the general nutritional condition and conditions of the nose, tonsils, teeth, thyroid, glands, heart, lungs, abdomen, spine; for tuberculosis and other organic changes; they examine skin, extremities, reflexes, genitalia—if necessary—and the length of the legs.

As the examinations are concluded, the office secretary collects the examination records.

Number of Examinations per Day.—With this force from 40 to 45 pupils can be examined during school hours.

Equipment of Room Space for Examinations.—A large room is desirable, which can be sectioned off by screens such as are used for the stage settings of the assembly hall, if such are available. Smaller screens make good dressing rooms. There should be separate spaces for weighing and measuring, equipped with a desk or table, scales, height measuring apparatus, tape measures, and calipers. The space allotted to the examiner of posture should be fitted with a long mirror, a table, and two chairs. The space occupied by the physician detailed to what may be called laboratory work should be in a separate room where it is quiet. She should be provided with Snellen's charts, a watch, a reliable, recently tested blood-pressure instrument, preferably one which can be quickly manipulated—such as the Tycos or Federal—and apparatus for testing hemoglobin. It is well known that the Tallquist scale is not very reliable, but it is doubtful if a Dare could be used in such rapid work unless one person were delegated to the task. The other two physicians will require only the stethoscope, tape line for leg measurements, an examining table, two stools and a chair.

Costume for Examinations.—As the public school does not permit the removal of enough clothing to place the stethoscope directly on the skin of the chest, and it is impossible to make accurate heart and lung diagnosis without doing so, the matter should be constantly and tactfully agitated until parents are educated to see the importance of the procedure. Even after their coöperation is assured it will be well to begin this more thorough type of work with boys. As soon as the advantage of sound medical work can be demonstrated, the parents will demand the same thoroughness for their daughters. Under present conditions girls should always be guarded from unnecessary exposure, they should retain their knitted underwear, shoes and stockings, and should be provided with a long straight strip of outing flannel with a hole in the middle for the head. The shoes should be unfastened, ready for rapid removal. In most private schools the physical education directors of boys advise the removal of all clothing during the medical examination.

The health examination card of many cities provides a space for a record of the social condition of the families from which the children come. This is very desirable in many instances, and can be procured by the nurse when she is making "follow-up" calls (note p. 916).

TABLE 13.—ESTIMATES OF PERCENTAGES OF PHYSICAL DEFECTS

	Wood (T. D.). Town children	Rapeer. School administration	Baker (S. J.). New York City	New York State	Penn. Fourth class towns	Chicago	Chicago (work certificate) mental defectives	Wood. Rural children
Pediculosis........								
Teeth...........	33.6	51.0	49.4	....	53.7	47.0	52.0	49.0
Pyorrhea.........	.....	......	....	....	....	....	13.0	
Adenoids.........	12.5	5.0	7.6	10.8	4.9			
Tonsils...........	16.4	6–10	10.4	....	26.3	23.0	43.0	28.0
Nasal catarrh.....	.....	......	....	14.6				
Mouth breathers...	.....	......	....	14.0				
Palate defects.....	.....	0.7						
Eyesight..........	13.4	7.0	7.3	....	17.8	12.6	10.7	21.0
Contagious eye diseases...........	.....	2.0						
Ears.............	1.28	2.0	0.42	....	3.3	....	5.4	4.78
Glands...........	2.7	1.0	.....	....	4.9	0.4	17.0	6.4
Hyperthyroid.....	.....	......	.....	....	....	....	16.0	
Hypothyroid	.....	......	.....	....	....	....	2.7	
Lung disease......	.....	......	0.12					
Heart disease, valvular...........	0.4	0.9	0.55	....	....	....	14.7	0.74
Rheumatism.. ...	.....	0.001						
Chorea...........	.....	0.5	0.31					
Skeletal deficiency.	.....	0.2	0.25					
Scoliosis and round shoulder........	.....	0.8						
Anaemia	1.5	1.0	.....	....	....	....	16.0	1.6
Malnutrition......	7.65	4.0	2.9	....	....	33.0	25.3	16.6
Speech defects.....	.....	0.9						
Untidiness........	.....	2.7						

TABLE 14.—DUNFERMLINE, SCOTLAND, 1906–1910

Nutrition..................	55.74 (medium and bad)	9.6 very poor
Teeth.....................	65.28	18.64 very poor
Vision.....................	8.70 (6/9 vision and worse)	9.42 (6/12 vision)
Ears......................	0.33	
Adenoids..................	0.19	
Mouth breathers..........	0.25	
Tonsils....................	0.04	
Glands....................	0.034	
Hernia....................	0.017	

It will be seen by Table 13 that there is considerable difference in the estimation of the inspectors of different cities. Rapeer estimates roughly that one-third of all school children have no defects, one-third have decayed teeth, and one-third have other serious defects. This is doubtless a low estimate. Rural children and defective children have a much higher percentage, as may be seen by reference to the last two columns. The figures of the work certificate group are based on the examination of 100 boys and girls over 14 years of age examined at the Orthogenic Institute of Rush Medical College, Chicago. The large number of defects found in this group is due to a general lowered

FRONT OF PHYSICAL EXAMINATION CARD

Name
Address......................................
Phone..................

City of.........................
Date of birth....................
Place of birth..................

School.........................
Entering Age....................
Nationality of Father...........
Nationality of Mother...........

Home hygiene inspection	Date (year)							Date		Nurse's record
Children in school: Boys............								Yr. 1		
Girls............								Grade		
Children not in school..............								Yr. 2		
Number of rooms...................								Grade		
Number sleep in one bed............										
Hours of home work................								Yr. 3		
Hours play out doors...............								Grade		
Other work outside school...........								Yr. 4		
Father or step-father...............								Grade		
Mother or step-mother.............										
Number of boarders................								Yr. 5		
Financial.........................								Grade		
Bath tub.........................								Yr. 6		
Ventilation.......................								Grade		
Number inside rooms...............								Yr. 7		
Number families using toilets.......										
Cleanliness.......................								Grade		
Coöperation with school............								Yr. 8		
Dispensary used...................										
Vaccination: Primary..............								Grade		
Secondary............										

X = Medical treatment referred. ⊗ = Cured. O = Improved, not cured. V = Minor, not referred. E = Excluded. R = Readmitted. (Nurse uses red ink.)

BACK OF PHYSICAL EXAMINATION CARD

Past diseases	Date																
Diphtheria									Age								
Scarlet fever									Date								
Measles									Height								
German measles									Weight								
Small pox									Height-weight coefficient + or −								
Chicken pox									General muscular								
Whooping cough									Grip (dynamometer): Right								
Mumps									Left								
Typhoid fever									Girth (chest): Inh.								
Malaria									Exh.								
Tuberculosis									Usual								
Pneumonia									Vital capacity								
Bronchitis									Length of leg: Right								
St. Vitus dance									Left								
Rheumatism									Pulse (sitting)								
Appendicitis									Pulse after exercise (four ¼ min.)								
Spinal									Blood pressure								
Bone disease									Pulse—blood pressure index								
Joint									Hemoglobin								
Sore throat									Vision: Right								
Ear ache									Left								
Ear discharge									Eye diseases								
Tooth ache									Hearing: Right								
Tooth abscess									Left								
Operations									Discharging ear								
Headaches (kind)									Nasal obstruction								
Ear ache									Adenoids								
Back ache									Tonsils enlarged, infected								
Frequent colds									Teeth (car., miss., mal. o.)								
Loss of breath									Glands								
Appetite									Goiter								
Use of coffee or tea									Posture								
Frequency of B. M.									Spine								
Bed wetting									Feet								
Use of tobacco									Other orthopedic								
Hours of sleep									Skin								
Nervousness									Heart								
Bites nails									Lungs								
									Hernia								
									Speech defect								
									Other conditions								

vitality, to the inefficiency of the group, and to parental inefficiency as shown by a lack of proper food, of good air, of hygienic habits, and of attention to defects.

NUTRITION

Barring infections, and perhaps the heating, ventilation and lighting of school rooms nutrition is the most important point to be considered in connection with school hygiene.

Table 15.—Weight to Height Increase

Height, inches	Boys			Girls		
	Weight, pounds	Increase per inch, pounds	Approximate age	Weight, pounds	Increase per inch, pounds	Approximate age
42	41.8	...	5	40.9	....	5
43	43.6	1.8	..	42.6	1.7	
44	45.6	2.0	..	44.5	1.9	
45	47.6	2.0	6	46.5	2.0	6
46	49.6	2.0	..	48.5	2.0	
47	52.1	2.5	7	50.7	2.2	7
48	54.6	2.5	..	53.2	2.5	
49	57.3	2.7	9	56.1	2.9	9
50	60.2	2.9	..	58.8	2.7	
51	63.2	3.0	10	61.4	2.6	10
52	66.3	3.1	..	64.4	3.0	
53	69.2	2.9	11	67.5	3.1	11
54	72.7	3.5	..	71.0	3.5	
55	76.4	3.7	..	74.9	3.9	
56	80.2	3.8	12	78.8	3.9	12
57	84.0	3.8	..	83.4	4.6	
58	87.9	3.9	13	87.9	4.5	
59	91.6	3.7	..	93.3	5.4	13
60	95.5	3.9	..	98.8	5.5	..
61	100.5	5.0	14	105.4	6.6	
62	105.6	5.1	..	115.7	10.3	14
63	110.7	5.1	15			
64	115.9	5.2				
65	121.0	5.1	16			
66	126.6	5.6				
67	136.1	9.5				

As a basis for nutritional standards it is necessary to have correct data regarding growth. L. E. Holt* has made a study of the differences in height of the Japanese, Italians, Germans, English, Poles and

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* Standards for Growth and Nutrition, American Journal of Diseases of Children (Dec., 1918), p. 359.

Russians. The variation is so great that it is important to consider it in dealing with the problems of nutrition confronting physicians and educators in a country composed of many heterogeneous groups, such as are found in the United States; therefore tables of height and weight based on age are giving place to the weight-height coefficient (the weight in kilograms or pounds divided by the height in centimeters or inches).

The approximate monthly gain in weight:

Table 16

Boys		Girls	
Age, years	Gain, ounces	Age, years	Gain, ounces
5– 8	6	5– 8	6
8–12	8	8–11	8
13–16	16	11–14	12
16–18	8	14–16	8
		16–18	4

Measurements and weights should be computed after the removal of shoes and coats.

B. T. Baldwin, of Swarthmore, Pennsylvania, has published an excellent "Individual Record Card in Physical Growth"(p. 930) which presents norms for height, for weight, and for lung capacity in the form of curves, as well as tables of the height-weight coefficients. These cards are taken with the child through the various grades, his own record being plotted in corresponding curves, thus keeping him constantly informed of his physical growth progress.

Tables based on age, with a monthly increment of both height and weight, have been compiled by Boas and Burk, and may be procured from the Elizabeth McCormick Memorial Fund, 6 North Michigan Avenue, Chicago, "Methods and Standards in the Weighing and Measuring of Children."

See also Julia C. Lathrop, Physical Standards for Working Children, Children's Bureau, U. S. Dept. of Labor.

The child's food requirements are fundamentally like those of the adult's, with some differences to be noted later. They are:

1. A sufficient number of calories.
2. A sufficient amount of protein for sustaining and building purposes.
3. Carbohydrates and fats in sufficient amount to provide for body fuel and energy, and to avoid an excessive draft upon the protein of body tissue.
4. Mineral salts, especially calcium, phosphorus, and iron, for building purposes and the regulation of body functions.
5. Foods that prevent acidosis.
6. Foods containing fat soluble A } Vitamins.
   Foods containing water soluble B }

7. Protective foods: milk, eggs, leaves.
8. Water for the regulating of body functions.

MEASURING SCALE FOR PHYSICAL DEVELOPMENT (BOYS)

English System

Form I

Name.. Schools..

Date of birth...Nationality.................. Examiners..

Date of examination........	......	....		....		....		....		....		....	
School year..................	Kg.	1		2		3		4		5		6	
Age..........................	5^2	6	6^2	7	7^2	8	8^2	9	9^2	10	10^2	11	11^2
Norm in inches.............. Height..........................	43.0	45.4	46.6	47.9	48.3	49.5	50.1	51.4	52.2	53.6	54.8	55.3	56.7
Weight-height coefficient....	.95	.95	.96	.98	1.07	1.09	1.12	1.17	1.19	1.23	1.30	1.33	1.33
Norm in pounds............ Weight..........................	41.0	42.9	44.8	46.9	51.7	54.2	55.9	60.4	62.1	66.9	71.4	73.2	75.5
Norm in cubic inches........ Breathing capacity..........	50.0	65.6	70.0	77.2	82.4	85.6	92.6	95.7	105.9	111.5	123.2	121.6	126.2
Vital-height coefficient.......	1.160	1.44	1.50	1.61	1.71	1.73	1.85	1.86	2.03	2.05	2.25	2.21	2.22
Date of examination........	....		....		....		....		....		....		......
School year..................	7		8		9		10		11		12		
Age..........................	12	12^2	13	13^2	14	14^2	15	15^2	16	16^2	17	17^2	
Norm in inches.............. Height..........................	57.1	57.8	58.2	59.5	61.0	62.2	63.7	65.1	66.3	67.4	67.5	67.5	
Weight-height coefficient.....	1.42	1.46	1.52	1.51	1.55	1.59	1.63	1.78	1.79	1.88	1.90	1.88	
Norm in pounds............ Weight..........................	81.0	84.6	89.5	90.0	94.9	98.9	104.9	115.9	118.9	127.1	128.5	127.0	
Norm in cubic inches........ Breathing capacity..........	134.0	140.5	150.8	152.9	162.5	173.8	191.7	210.0	212.6	222.6	236.4	238.0	
Vital-height coefficient.......	2.35	2.52	2.59	2.57	2.66	2.79	3.00	3.23	3.21	3.30	3.50	3.53	

These norms represent well-developed children with school-medical inspection and physical training. A small child for a given age may be well developed if the *coefficients*, height, weight, and breathing capacity relationships, are normal and approximate those indicated. The formula is

Weight ÷ height = weight-height coefficient.

Breathing capacity ÷ height = vital-height coefficient.

For example. For 5^2 years, 41 lbs. ÷ 43 in. = .95 weight-height coefficient.

In the metric system use height in centimeters, weight in kilograms, and breathing capacity in liters. The English weight-height coefficient norms × .179 = metric weight-height coefficient norms. The English vital-height coefficient norms × .00645 = metric vital-height coefficient norms.

School year......	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12
Health..........													Vision............													Hearing..........												
Vaccination......													Glands...........													Posture..........												

Note: G = Good M = Medium P = Poor C = Corrected.

CHART 7.

In order that vital processes may go on in the body, the tissues, in warm-blooded animals, must be kept at a certain degree of temperature, and must have brought to them by the blood a certain quantity of food in solution which can be assimilated and which will compensate for the katabolism resulting continuously as the product of combustion. This is designated by Benedict as "the energy requirements for maintenance, or overhead charges."* The growing child also requires additional food for body development, and for both the ordinary and excessive physical activity which characterizes this period.

Basal metabolism, which is accurately estimated by an instrument called the calorimeter,† is the amount of heat production necessary to meet maintenance requirements only. Experiments in basal metabolism are performed with the body in complete muscular repose and after 12 hours' starvation. If only the amount of food necessary to meet the requirements of basal metabolism were ingested, pronounced malnutrition would soon result, as the natural growth in height must be accompanied by a parallel growth in weight, and provision must be made for these and for physiological and muscular energy.

Formerly basal metabolism for both adults and children was computed upon the square meter of body surface. Benedict has shown more recently‡ that this computation cannot be used for children, and presents a chart from which the following tables for boys and girls have been derived:

TABLE 17.—TOTAL CALORIES REFERRED TO WEIGHT (BASAL METABOLISM)

Kilograms	Calories, girls	Calories, boys
2	100	100
6	350	350
10	520	560
14	640	700
18	760	815
22	850	910
26	970	1020
30	1040	1130
34	1190	1200
38	1250	1300
42	1300	1400

A study of this table shows that there is a greater increment of metabolism at the lower weight limits than at the higher, and also that there is far less difference in metabolism between boys and girls than might be expected if one takes into consideration the difference of their life habits (p. 964).

1. Caloric Estimation (Food Requirements as to Quantity).—The prevalent method of measuring food values, and basal metabolism, is by calories or heat units, determined by the calorimeter. The calorie or heat unit is simply a standard of measure for heat as the pint is for milk or water.

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* Energy Requirements of Children from Birth to Puberty, Boston Medical and Surgical Jour., clxxxi, No. 5 (July 31, 1919).

† *Ibid.*, or Lusk, "Science of Nutrition."

‡ *Ibid.*

One heat unit or large calorie is the amount of heat required to raise 1 kg. or 2.2 pounds of water 1°C. (1.8°F.).

15 grains (1 gm.) pure protein burned in the body raises 4 kg. of water one calorie.
15 grains (1 gm.) pure carbohydrate burned raises 4 kg. of water one calorie.
15 grains (1 gm.) pure fat burned raises 9 kg. of water one calorie.

We say therefore, that

1 gm. protein furnishes four heat units or calories.
1 gm. carbohydrate furnishes four heat units or calories.
1 gm. fat furnishes nine heat units or calories.

For example: 1 ounce or 30 gm. of olive oil furnishes nine times 30 or 270 calories.

von Pirquet has developed another system of measuring food values and food requirements, which has as its nutritional unit 1 gm. of mother's milk, equal to 0.67 large calorie. This he refers to as N. E. M. (nem) (Naehrungs—Einheit—Menge). On this basis he has estimated the values of different foods. For example; sugar has 6 nem per gram, fresh spinach 0.4 nem, fresh meat 2 nem, etc. The index for the amount of food required is the intestinal area which represents the surface governing the amount of food absorbed. He calculates that the length of the intestines is 10 times the sitting height, and the width of the intestine $1/10$ of the sitting height. If Si represents sitting height, then $10Si \times \frac{Si}{10} = Si^2$. In other words, if 80 cm. is the sitting height, the food requirement is 80 × 80, or 6,400 nem.* Feeling with von Pirquet that the calorie is too abstract an entity for the child to understand, some dietitians have taken the teaspoon as their unit of measure. They draw comparisons for the child between a teaspoonful of fresh peas and a teaspoonful of dried peas, etc. It has been quite conclusively shown in nutritional clinics that children have an adequate working concept of the calorie as they have of degrees of temperature. It would seem therefore that as the calorie is the fundamental unit for the quantitative measurement of food that it is wiser to use it. One hundred calorie portions help to make food values clear as does the "customary measure" also which has the added advantage of being a direct association (paragraph on "Association," p. 988).

Mrs. Mary Swartz Rose ("Feeding the Family") has given the number of calories per pound per day that meet not only the requirements of basal metabolism, but those of growth and ordinary muscular activity:

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* For further description see von Pirquet, C. F., "System der Ernährung, Berlin, Julius Springer (1917); Schick, B., Das v. Pirquetsche System der Ernährung, Ergebn. d. Inn. Med. u. Kinderh., xvi (1919), p. 384; Faber, Harold, von Pirquet's Feeding System, Amer. Jour. of Dis. of Children, xix, No. 6 (June, 1920), p. 478.

TABLE 18.—MAXIMUM AND MINIMUM DAILY CALORIES REQUIRED ACCORDING TO WEIGHT FOR PERSONS ENGAGED IN LIGHT PHYSICAL WORK

AGE, YEARS	CALORIES PER LB. PER DAY
1– 2	45–40
3– 5	40–35
6– 9	35–25
10–13	30–25
14–17	25–20
18–25	20–17
60–70	15–12

Some Food Facts—Mary Swartz Rose, Columbia University.

Studies have been made by Gephart* of boys of St. Paul's School at Concord, New Hampshire, which emphasize the importance of very liberal allowances of food at the prepubertal and pubertal periods. These boys, who were between the ages of 13½ and 16 years, consumed on an average 5,000 calories a day, considerably more than the amount required by farmers at hard work. Lusk says that the basal requirement of boys when asleep is 25 per cent. above that of adults, and that the total fuel intake is three times that of this basal level. He further adds that a lack of appreciation of this factor causes much of the current malnutrition of children of school age.

Other factors which enter into alterations in metabolism and weight are the activity of the thyroid gland—either diminished or increased—anemia, the amount of exercise, extremely hot or cold baths, clothing, the wind, humidity and altitude.

2. Protein.—A sufficient amount of protein should be eaten for sustaining and building purposes. The amino-acids of proteins are found in both animal and vegetable foods, but they are not equally usable. Some of the amino-acids found in vegetable foods must be worked over by the animal body of lower animals into a form that is assimilable by the human body. Corn, for instance, which has no tryptophan (one of the most important of amino-acids for man), is excellent food for the cow, in whose body it becomes converted into muscle or milk protein, in which form it is available for the building of human tissue. Protein is absolutely necessary to life,† but it is not desirable in excessive quantities, 15 per cent. of the total food intake at the most being sufficient. Mrs. Rose estimates that while 2 to 3 protein calories per pound are ample for the adult, a growing child may require more; 2 to 4, or even 4 to 6 especially in cold weather. Milk protein is doubtless more valuable than meat protein.‡ McCollum says "Lacto vegetarianism when the diet is properly planned is the most highly

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[*] Boston Med. and Surg. Jour., clxxvi, No. 17 (1917), from the Russell Sage Institute of Pathology.

[†] Maver, Maria B., Nutritional Edema and War Dropsy, J. A. M. A., lxxiv, No. 14 (April 3, 1920), p. 934.

[‡] Hindhede, M., The Effect of Food Restriction During War on Mortality in Copenhagen, J. A. M. A., xxiv, No. 6 (Feb. 7, 1920), p. 381.

satisfactory plan which can be adopted in the nutrition of man." School children should have from one pint to one quart of milk daily.

3. **Fats and carbohydrates** are necessary as sources of energy and as conservers of protein. Carbohydrates furnish about two-thirds of the energy produced by the human organism, and are the most economical foodstuffs.* The ingestion of fat as fat is for the purpose of providing fuel, and also for the purpose of relieving the intestine of excessive carbohydrate digestion and absorption.

4. **Mineral salts** are extremely important in the building of body tissue.† The average boy between the ages of 6 and 14 years requires at least 0.39 gm. *calcium* daily. Unless water is very hard it cannot be depended upon to supply much calcium, which must therefore be derived from milk, egg yolk, beans, nuts, carrots, grains, etc.‡ Milling removes half of the calcium content from grain, therefore the coarser, darker flours are to be preferred. Calcium is not only a body builder, but it conserves both protein and iron in metabolism.

Phosphorus is essential to the growth of all the tissues of the body, it is also of importance in preventing acidosis. It is estimated that man requires from one-fortieth to one fiftieth as much phosphorus as protein.‖ It is found most abundantly in egg yolk, entire wheat, dried beans, nuts, oatmeal, beef, milk, lettuce, cider vinegar and oysters.

Iron.—The amount of iron in the body is small—only 3 gm. in an adult—but as in the form of hemoglobin it furnishes the mechanism for oxidation, it is of extreme importance. Iron is absorbed from the small intestine and enters into firm organic combination with the body protein. Inorganic or medicinal iron is absorbed and utilized only in the presence of organic iron; therefore in giving medicinal iron a careful dietary plan should be made, including iron-containing foods. From 7 to 10 mg. of organic iron is required daily by the growing child. It occurs in greatest abundance in egg yolk, dried peas and beans, spinach and lettuce, beef, oatmeal, and entire wheat, dried prunes, nuts and raisins.

5. Foods preventing acidosis are potatoes, oranges, raisins, apples and bananas.

6. Fat-soluble A is a vitamin found in minute amounts in milk, egg yolk, in the leaves of plants, and glandular organs, the liver of the cod furnishing an important source in the form of cod-liver oil. Recent investigations of Osborne and Mendel** have demonstrated that the tomato and orange are not only anti-scorbutic but that they afford very valuable sources of both fat-soluble A and water-soluble B.

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* See Lusk, "Science of Nutrition."

† Sherman, Henry C., Quantitative Aspects of Nutrition, Teachers' College Bulletin, Second Series, No. 15 (March 25, 1911).

‡ Editorial, J. A. M. A., lxxiv, No. 16, p. 1103.

‖ Editorial, J. A. M. A., lxxiv, No. 12, p. 804.

** See references in editorial of the Jour. Amer. Med. Assn., lxxiv, No. 25 (June 19, 1920).

Water-soluble B is a vitamin found in the outer covering of rice and other seeds, in milk, vegetables and fruit.

The following is a list of foods with their relative proportion of vitamins, published jointly by the Lister Institute and Medical Research Committee:

CHART 8.

Classes of foodstuff	Fat-soluble A or anti-rachitic factor	Water-soluble B or anti-neuritic (antiberiberi) factor	Antiscorbutic factor
Fats and Oils:			
Butter	+++		
Cream	++		
Cod-liver oil	+++		
Mutton fat	++		
Beef fat or suet	++		
Peanut oil	+		
Fish oil, whale oil, etc	++		
Margarin prepared from animal fat	Value in proportion to amount of animal fat contained		
Nut butters	+		
Meat, Fish, etc.:			
Lean meat (beef, mutton, etc.)	+	+	‡
Liver	++	++	
Kidneys	++	+	
Heart	++	+	
Brain	+	++	
Sweetbreads	+	++	
Fish, white	....	very slight, if any	
Fish, fat (salmon, herring, etc.)	++	very slight, if any	
Fish, roe	+	++	
Canned meats	?	very slight	
Milk, Cheese, etc.:			
Milk, cow's whole, raw	++	+	+
Milk, skim, raw	....	+	+
Milk, dried, whole	less than ++	+	less than +
Milk, boiled, whole	undetermined	+	less than +
Milk, condensed, sweetened	+	+	less than +
Cheese, whole milk	+		
Eggs:			
Fresh	++	+++	?
Dried	++	+++	?
Cereals, Pulses, etc.:			
Wheat, maize, rice, whole grain	+	+	
Wheat germ	++	+++	
Wheat, maize, bran	....	++	
Linseed, millet	++	++	
Dried peas, lentils, etc	....	++	
Soy beans, haricot beans	+	++	
Germinated pulses or cereals	+	++	++
Vegetables and Fruits:			
Cabbage, fresh (raw)	++	+	+++
Cabbage, fresh (cooked)	....	+	+
Cabbage, dried	+	+	very slight
Cabbage, canned	....	....	very slight
Swede (rutabaga) raw expressed juice	....	....	+++
Lettuce	++	+	
Spinach (dried)	++	+	
Carrots, fresh raw	+	+	+
Carrots, dried	very slight		
Beetroot, raw, expressed juice	....	....	less than +
Potatoes, raw	+	+	
Potatoes, cooked	....	....	+
Beans, fresh, scarlet runners, raw	....	....	++
Onions, cooked	....	....	+ at least
Lemon juice, fresh	....	....	+++
Lemon juice, preserved	....	....	++
Lime juice, fresh	....	....	++
Lime juice, preserved	....	....	very slight
Orange juice, fresh	....	....	+++

CHART 8.—*Continued.*

Classes of foodstuff	Fat-soluble A or antirachitic factor	Water-soluble B or antineuritic (antiberiberi) factor	Antiscorbutic factor
Raspberries	....	....	++
Apples	....	....	+
Bananas	+	+	very slight
Tomatoes (canned)	....	....	++
Nuts	+	++	
Miscellaneous:			
Yeast, dried	....	+++	
Yeast, extract and autolyzed	?	+++	
Malt extract	....	+ in some specimens	

None of the three factors were found in:
- Lard.
- Olive, cottonseed, cocoanut or linseed oils.
- Cocoa butter.
- Hardened fats, animal or vegetable in origin.
- Margarin from vegetable fats or lard.
- Cheese from skim milk.
- Polished rice, white wheaten flour, pure corn flour, etc.
- Custard powders, egg substitutes, prepared from cereal products
- Pea flour (kilned)
- Meat extract.
- Beer.

7. McCollum's* biological studies have shown that there are dietary deficiencies in seeds, tubers, roots, and meat, though they are valuable adjuncts in diet, if there is more or less protein, liberal amounts of mineral salts and an ample supply of milk, eggs and leafy vegetables which contain vitamins; the latter known as "Protective Foods."

A word may be added concerning the "Congenial Calorie of the Candy Shop." The boys of Gephart's study averaged 640 calories daily in chocolate bars or sundaes, and the young women of Vassar College take 10 per cent. of their nourishment in calories derived from such sources. Sugar is used in large quantities by lumbermen and others whose physical exercise is excessive.† Nuts, often used in candies, provide valuable protein, fat and iron—especially the peanut, almond, brazil nut and hazel nut. Sweets, however, must take a very secondary place in diet; otherwise, on account of their palatability they will supersede the more vital foods from which protein and the other basic substances are derived. Children should be allowed to eat candy only after meals.

8. The free use of water is extremely essential as an aid to prompt "evacuation of the undigested residue from the intestine before extensive absorption of products of bacterial decomposition of proteins can take place" (McCollum).‡

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* "The Newer Knowledge of Nutrition."

† Editorial, J. A. M. A., lxxi, No. 17 (Oct. 26, 1918), p. 1410, and *ibid.*, lxxi, No. 10, p. 826.

‡ Koessler, Karl K., Studies on Proteinogenous Amines, The Jour. of Biol. Chemistry, xxxix, No. 3 (1919).

MALNUTRITION

Holt regards a child as malnourished if 10 per cent. below weight for height from 6 to 10 years, and if 12 per cent. below from 11 to 16 years. The *annual rate of increase* he believes to be an even more important guide. (See table, p. 928.) Nutrition figures for the 1,000,000 school children of New York City show that 173,000 are normal, 611,000 passable, and 216,000 (or 21 per cent.) seriously under nourished. Dr. Thomas D. Wood estimates that from 15 to 25 per cent. of the school children of the United States are undernourished. This is important in view of the fact that malnourished individuals under the age of 30 show a much poorer life expectancy than those who are normal or overnourished, and school progress is also shown to depend to a certain extent upon nutrition.* The malnourished child is not always underweight; therefore, in this connection it is necessary to take into consideration the firmness and flabbiness of muscle tissue, the color of the skin and mucous membranes, the alertness or dulness of facial expression, indications of natural curiosity and power of concentration, the state of the disposition as to timidity, irritability, restlessness, the character of sleep, and the attitude toward food.†

The **causes** of malnutrition are faulty health habits, acute disease, physical defects, especially enlarged or infected tonsils, adenoids, deviated septa and sinus infection, chronic otitis media, carious teeth, eye-strain, syphilis, tuberculosis, chronic overfatigue; nervous excitement in or out of school due to examinations, too much home work, movies, too many outside activities—either mental or social—worry, too little outdoor activity, too little sleep, faulty dietary habits, *i.e.*, tea and coffee, rapid eating, candy and sweets in too large quantities and taken either between meals or before meals, and the substitution of "cakes" for bread which, with coffee, forms the breakfast of the children of many ignorant and poor parents. It has been shown that while poverty is doubtless a cause, parental ignorance and shiftlessness are much larger contributing factors.

Dr. W. R. P. Emerson of Boston has given nutritional work a great impetus by means of nutritional clinics organized both in and out of public schools in Massachusetts, Illinois, New Hampshire, Rhode Island, New York, Pennsylvania, Tennessee, Georgia, Wisconsin, Kentucky, Michigan, Ohio, and Montreal, Canada, California, Colorado, Indiana, Iowa, Alabama, Honolulu, Labrador. Each child is weighed and measured weekly, and is provided with a large chart on which the normal height-weight coefficient curve is drawn. In some of the public schools of Chicago the height and weight for age curve is also presented (Fig. 246). Various devices—gold stars, red stars, different colored numerals, etc.—are used in grading the children, and are pasted on their charts to indicate the amount of rest, the

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*Blanton, Smiley, Mental and Nervous Changes in the Children of the Volkschulen of Trier, Germany, Caused by Malnutrition, Mental Hygiene, iii, No. 3 (July, 1919).

† See Roberts, Lydia, What is Malnutrition? U. S. Dept. of Labor, Children's Bureau Publication, No. 59.

Board of Education
City of Chicago

CHICAGO PUBLIC SCHOOLS
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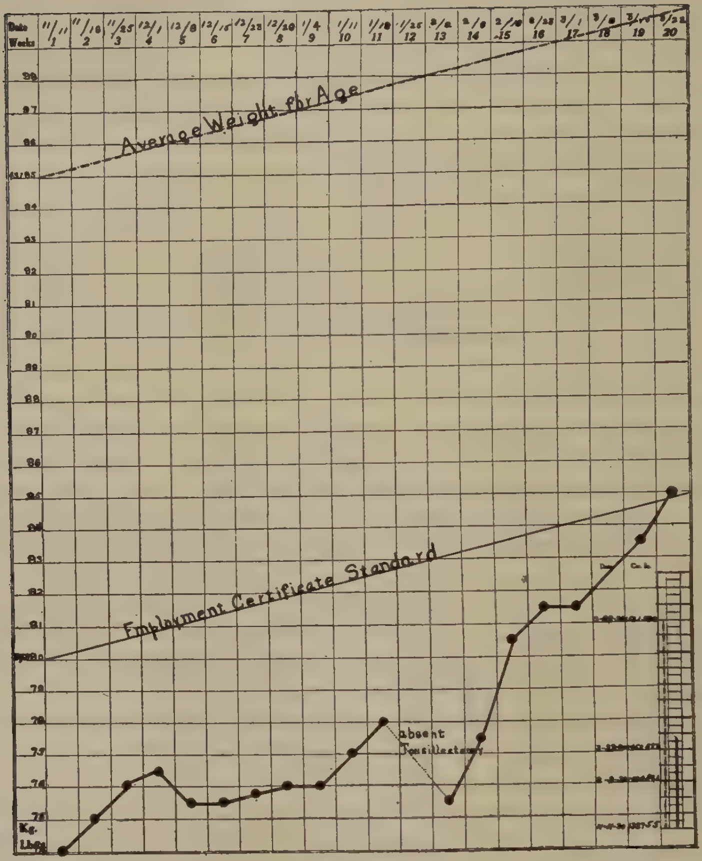

Age 13-8 Grade 6A
Height 139.7 Cm. 56 In.
Weight 33.6 Kg. 74 Lbs.
Underweight 9.5 Kg. 22 Per Cent.
Average Height for Age 152.1 Cm.
Average Weight for Age 43.1 Kg.
Average Weight for Height 34.8 Kg.
B. C. O. 391.

Physical Defects Corrected
12-7-20 Tonsillectomy.

Co-operation
Lunches
Rest Periods

FIG. 246.—The diagonal straight and irregular lines across the body of the chart register weight increase. The thermometer at the lower right hand corner registers height increase. The broken line at the left of the thermometer indicates the *average* height for age and corresponds to the line across the body of the chart indicating average weight. The shorter solid line in the center of the thermometer indicates *actual* height increase corresponding to the irregular curve across the chart which registers actual weight increase. The employment certificate standard for weight is registered across the chart, that for height in the thermometer not being given. This thermometer is so graphic that it strongly appeals to the child. Molesworth's "Metric Tables" is a convenient and inexpensive little book which those working with kilograms and pounds, centimeters and inches will find invaluable.

highest weekly gain, etc. All of these devices are great incentives to children, and are producing remarkable results. Miss Roberts emphasizes the necessity of visits to the homes in the most aggravated of their clinic cases, as it is sometimes necessary to train the mothers "Line upon line, precept upon precept" in order to gain permanent results. She also provides each child with a daily record sheet on which the child notes his bed time, rising time, hours of sleep, open windows, use of tooth brush, hours out of doors, baths, milk, potato, other vegetables, fruit, meat, egg or fish, iron foods, food taken between meals, and coffee or tea.

The following articles will be found of use as guides in work of this kind:*

Caloric Estimation.—The correct method of reaching an accurate estimate of the caloric value of food, which the child actually eats per day, is to make a tabulated list of the articles of food eaten, stating the exact amount taken for breakfast, lunch, dinner and "between times," for two successive days so as to obtain an average per day. Data for this estimation are found in Table 19. Compare the total eaten with the total actually required per day, the latter estimated by multiplying the subject's proper weight for his height and age by the proper number of calories per pound for his age (Table 18).

Mrs. Rose gives the following dietary for a child of 8 to 10 years Breakfast (7–7:30 a.m.): A mild fruit, well-cooked cereal, dry toast or stale bread, butter and milk. Dinner (12–12:30 p.m.): A soft-cooked egg, or small portion of fish, lamb, chicken or bacon, potatoes or rice, watery cooked vegetable, milk, bread, butter or jelly, nutritious pudding or stewed fruit, and plain cake. Supper (5:30–6 p.m.): Cream soup or milk toast, or rice and milk, or baked potato, milk to drink, bread, nutritious pudding. A total of 1,700 to 2,000 calories.†

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*Rich, Katherine B., Nutritional Work in Public Schools, J. A. M. A., lxxv, (Nov. 27, 1920).

Rich, K. B., Nutritional Work in Public Schools, *ibid.*, lxxvi, No. 15 (April 9, 1921).

Brown, Maud A., A Study of Malnutrition of School Children, *ibid.*, lxxv, No. 1 (July 3, 1920), p. 27.

† Rose, Mrs. Mary Swartz, "Feeding the Family."

TABLE. 19.—TABLE OF FOOD VALUES

Customary measure	Food	Actual weight	Calories	Nutrients yielded			In grams per 100 calories of food material		
				Protein	Fat	Carbohydrate	Calcium	Phosphorus	Iron
	Beverages								
1 glass	Milk	8 oz.	159.1	30.0	84.0	46.0	0.174	0.134	0.00035
1 glass	Buttermilk	8 oz.	80.0	31.0	9.3	47.0	0.331	0.262	0.00068
1 tablespoonful	Cream, 20 per cent	16.0 gm.	30.0	2.0	28.0	2.0	0.050	0.044	0.0001
1 cup	Cocoa with sugar	194.0 gm.	227.0	29.0	82.0	64.0			
1 cup	Milk eggnog	239.0 gm.	117.4	52.0	118.0	57.0			
1 glass	Plain lemonade	221.6 gm.	174.0	.....	......	112.0			
	Fruits								
1 medium sized	Orange	130.0 gm.	70.0	.....	4.7	68.0	0.088	0.040	0.00039
1 medium sized	Banana	100.0 gm.	100.0	6.0	5.0	90.0	0.009	0.031	0.00061
1 medium sized	Apple	142.0 gm.	68.1	2.0	4.0	63.0	0.012	0.020	0.00048
½ cup	Strawberries, hulled	73.0 gm.	28.7	2.9	4.0	22.0			
6 large	Prunes, not cooked	93.0 gm.	151.7	4.0	......	148.0	0.018	0.035	0.00100
½ cup	Figs, raisins and dates, dried	75.0 gm.	262.0	7.0	19.0	227.0	0.051 (figs)	0.037	0.00095
							0.019 (raisins)	0.038	0.00139
	Cereals								
⅓ cup	Oatmeal, cooked	81.5 gm.	51.9	9.0	4.0	39.0	0.017	0.099	0.00096
⅓ cup	Cereal, dry and								
4 tablespoons	Cream	7.5 gm.	29.5	5.0	2.0	22.0			
1	Shredded wheat	30.0 gm.	110.0	12.0	5.0	94.0			
	Bread and Cake								
1 slice moderate	Bread, white	28.0 gm.	75.5	10.0	4.0	62.0	0.011	0.035	0.00035
1 slice moderate	Bread, brown	69.0 gm.	159.6	15.0	11.0	133.0	0.056	0.082	0.0013
1 slide moderate	Whole wheat bread	21.0 gm.	52.7	8.0	1.9	43.0	0.020	0.071	0.00065
1 slice 2 × 4 × ½	Sponge cake	20.0 gm.	75.0	6.0	19.0	53.0			
	Layer cake								
	Soups								
¾ cup	Clear	177.0 gm.	20.9	18.04	......	2.87			
¾ cup	Vegetable	179.0 gm.	25.0	21.32	......	3.69			
¾ cup	Cream of tomato	178.0 gm.	181.9	18.45	116.25	47.15			
¾ cup	Split pea soup	178.0 gm.	100.0	26.0	2.0	72.0			
	Vegetables								
1 medium size	Potato, baked	95.0 gm.	119.4	13.0	0.9	106.0	0.016	0.069	0.00156
1 medium size	Potato, boiled	91.0 gm.	88.3	9.0	0.9	78.0			
½ cup	Rice, boiled	99.0 gm.	111.6	11.0	0.9	99.0	0.001	0.027	0.00026
½ cup	Corn	100.5 gm.	101.0	11.0	11.0	78.0	0.006	0.102	0.00079
2¼ oz.	Lima beans	63.6 gm.	103.5	21.0	40.0	77.0	0.020	0.096	0.00200
⅔ cup	Beets	117.0 gm.	50.0	7.0	1.0	42.0	0.064	0.084	0.00130
½ cup	Tomatoes	128.0 gm.	29.9	6.0	1.9	21.0	0.050	0.113	0.00175
⅓ cup	String beans	110.0 gm.	23.2	5.0	0.9	17.0	0.110	0.126	0.00265
⅓ cup	Green peas	62.0 gm.	35.0	9.0	0.9	25.0	0.026	0.120	0.00165
3 oz.	Spinach	85.0 gm.	25.0	10.0	3.0	15.0	0.281	0.285	0.01506
¼ large head	Lettuce	69.0 gm.	12.5	3.0	1.8	7.6	0.224	0.224	0.00785

		Eggs								
1	whole		50.0 gm.	76.8	27.5	49.3	......	0.045	0.122	0.00205
1	yolk		15.0 gm.	55.0	10.3	46.5	......	0.025	0.100	0.00185
		Meat								
1	slice 4 × 4 × ¼	Lean	50.0 gm.	70.0	47.15	23.25	......	0.058	1.078	0.0150
1	slice 4 × 4 × ¼	Medium fat	50.0 gm.	105.0	47.15	83.7				
1	slice 4 × 4 × ¼	Fat	50.0 gm.	200.0	34.85	167.4				
1⅕	cups	Stew and vegetables	255.0 gm.	283.0	46.0	127.5	109.9			
¾	cup	Creamed chip beef	180.0 gm.	250.0	40.0	162.0	48.0			
2	slices	Bacon	14.0 gm.	126.0	14.35	111.6				
		Fish								
1	piece	Halibut	75.0 gm.	87.7	53.3	33.7	......	0.109	1.148	0.0055
1	piece	White fish	75.0 gm.	61.1	36.9	24.2				
		Desserts								
½	cup	Custard	161.0 gm.	182.0	30.3	69.7	81.6			
1	slice	Ice cream	70.0 gm.	153.0	8.6	97.6	46.7			
½	cup	Lemon jelly	95.0 gm.	121.8	6.6	0.009	115.2			
2	half tablespoons	Apple sauce	90.0 gm.	140.0	.....	0.9	135.7			
1	piece	Short cake	184.0 gm.	472.0	33.2	228.8	179.6			
1	sector 3-in. at circumference	{ Apple pie	96.0 gm.	200.0	6.0	82.0	112.0			
		{ Lemon pie	90.0 gm.	300.0	15.0	81.0	204.0			
		Miscellaneous								
1	pat or cube	Butter	10.0 gm.	80.0	.....	79.0	......	0.002	0.002	0.00003
1	inch cube	Cheese	17.0 gm.	77.0	20.1	56.7	0.2	0.212	0.156	0.00030
1		Sandwich, egg	100.0 gm.	299.0	39.36	118.1	141.4			
1		Sandwich, ham	70.0 gm.	233.0						
1		Sandwich, jelly	42.0 gm.	174.0						
1	medium size	Olive	7.0 gm.	15.0	.....	14.0	2.0	0.041	0.004	0.00097
1	teaspoon	Olive oil	4.0 gm.	37.0	.....	37.2				
1	scant tablespoon	Sugar	15.0 gm.	50.0	.....	......	49.5			
1	tablespoon	Maple syrup	21.0 gm.	61.5	.....	......	61.5			
10	shelled	Peanuts	17.0 gm.	96.2	18.0	61.0	16.8	0.013	0.073	0.00036
10	shelled	Almonds	10.5 gm.	70.3	9.0	53.9	7.4			
2	shelled	Brazil nuts	15.0 gm.	100.0	10.0	86.0	4.0			
12	meats	Pecans	15.0 gm.	100.0	5.0	87.0	8.0			
1	tablespoon	Mayonnaise dressing	15.0 gm.	100.0	1.0	97.0	2.0			
1½	tablespoon	French dressing	22.5 gm.	100.0	.....	100.0				
		(Hershey) chocolate bar 8 ¢	....	200–300						
		Ice cream soda	....	202–467						
1		Ice cream cone	....	100.0						
1		Soda cracker	....	30.0						
1	pint	Ginger ale	....	150.0						

From Department of Household Administration, University of Chicago. Sherman, Henry C., "Chemistry of Food and Nutrition." Appendix B, Table II, p. 421. Rose, Mary S., "Feeding the Family."

SCHOOL LUNCHES

In the United States school lunches usually consist of milk and crackers, or cocoa and crackers at 10 o'clock; and at noon some hot dish to supplement a cold lunch brought from home.

WEEKLY MENU IN SCHOOL WITH PENNY LUNCHES AND FIVE-CENT NOON DINNER*

Monday:	(1)	Baked beans and roll	5¢
	(2)	Cocoa or milk	2¢
		Crackers or ice cream	1¢
Tuesday:	(1)	Vegetable soup and roll	5¢
	(2)	Same choice as Monday.	
Wednesday:	(1)	Creamed beef on toast and roll	5¢
	(2)	See Monday.	
		Dates	1¢
Thursday:	(1)	Macaroni with tomato sauce and roll	5¢
	(2)	See Monday.	
		Jam sandwich	1¢
Friday:	(1)	Creamed salmon and roll	5¢
	(2)	See Monday.	

(This provides one-third of a child's daily ration.)

In open air or pretubercular schools† food furnished in school during the day consists of the following, with equivalent variations:

One cup of milk at 10 a.m. and 3 p.m. Lunch: Beef loaf with tomato sauce, potatoes, apricots, bread and milk. Creamed eggs, potatoes, or lettuce or spinach, raisins, bread and milk. This provides one-half of a child's daily ration.

The school lunch box may contain: sandwiches, fruit, simple cake or cookies. Milk or mild cocoa, or hot soup should be provided by the school. The equipment for school lunches amounts to approximately $500. In large schools it is necessary to have a cook and an assistant who supervises the older school children who serve at the counter. New York City has a central kitchen plan from which food is distributed to every four or five schools.‡ Their estimates show that this plan saves $^{19}/_{20}$ of a cent in food and two mills per child in labor, supervision and transportation, which is to be considered in a large system.

Helpful monographs can be secured from:

Dietetic Bureau, 46 Cornhill, Boston, Mass.
The School Luncheon, Oregon Agricultural College, Corvallis, Oregon.
Diet for the School Child, Child Health Organization, 156 Fifth Ave., New York.
The Rural School Lunch, University of Illinois, Urbana, Ill.
The Box Luncheon, N. Y. State College of Agriculture at Cornell University, Ithaca, N. Y., ii, No. 43.

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* Rose, Mrs. M. S., "Feeding the Family."

† See Elizabeth McCormick Fund, Chicago.

‡ Brown, E. F., Feeding School Children in New York City, The Journal of Home Economics (March, 1915), p. 119.

School Lunches, U. S. Dept. of Agriculture, Farmers' Bulletin No. 712.

Domestic Science in Rural Schools, Minnesota Farmers' Library, University Farms, St. Paul, Minn., Extension Bulletin No. 19.

Adele S. Jaffa, A Standard Dietary for an Orphanage, State Board of Charities and Corrections, California.

School Lunches in Philadelphia, School Lunch Committee, 1505 Land Title Bldg., Philadelphia.

Commission on Milk Standards, U. S. Public Health Service, Washington Reprint, No. 386 from Public Health Reports.

Germ Content of Milk, University of Illinois, Agricultural Experiment Station, Bulletin No. 204, Urbana, Ill.

A most excellent guide is Mrs. Mary Swartz Rose, "Feeding the Family."

RESPIRATORY DETERMINATION

Chest measurements should be made just above the nipple during forced inspiration, forced expiration, and ordinary breathing.

TABLE 20.—CHEST EXPANSION (DUNFERMLINE, SCOTLAND, 1906–1910)

Age	Number examined	Expansion (inches)
7	50	1.94
8	170	2.14
9	211	2.26
10	214	2.55
11	236	2.59
12	238	2.23
13	212	3.09
14	28	3.35

Lung capacity is measured by the spirometer, preferably of the wet type, fitted with detachable wooden mouthpiece. For methods of use see "Manual of Mental and Physical Tests"—Whipple.

TABLE 21.—NORMS OF VITAL CAPACITY (SMEDLEY)

Age	Boys, centimeters	Girls, centimeters	Age	Boys, centimeters	Girls, centimeters
6	1023	950	13	2108	1827
7	1168	1061	14	2395	2014
8	1316	1165	15	2697	2168
9	1469	1286	16	3120	2266
10	1603	1409	17	3483	2319
12	1883	1664	18	3655	2343

VITAL INDEX

The relation of vital capacity to weight has been estimated both on a basis of pounds and of kilograms. In either case, the vital index is the result of dividing the vital capacity in cubic centimeters by the weight and represents the number of cubic centimeters of air space in the lungs for each kilogram or pound of body weight. This ratio shows whether the pupil has a lung capacity adequate for his body.

The following table from Kotelmann shows V. C. based on kilograms:

Cm. of air space in the lungs for each kgm. of weight:

Table 22

Age	9	10	11	12	13	14
	69.32	69.37	69.18	67.51	66.75	64.07
Age	15	16	17	18	19	20
	63.18	65.94	65.77	64.28	66.22	65.01

The following table taken from Smedley shows V. C. based on pounds:

Table 23

Age	6	7	8	9	10	11	12	13	14	15	16	17	18
Boys	23	24	25	25	25	25	25	25	25	25	26	27	27
Girls	22	24	23	23	23	23	22	21	20	20	20	20	20

The above table was secured by using Smedley's norms of weight (Table 24) and vital capacity in table 22 and computing the vital index in terms of the number of cubic centimeters of air capacity per pound by weight, by converting the weight in kilograms to pounds and dividing this weight in pounds into the V. C. It will be noticed that girls show a falling off after the age of 11. This may be due to tight lacing which was in vogue at the time these tables were compiled. The first horizontal column gives the age, underneath is given the V. C. for boys and girls.

Table 24.—Norms of Weight in Kg. With Clothing (Smedley)

Age	Boys	Girls	Age	Boys	Girls
6	19.738	18.870	13	38.084	38.974
7	21.613	20.974	14	42.696	44.219
8	23.817	23.010	15	47.993	48.161
9	26.336	25.257	16	53.238	50.652
10	28.707	27.795	17	57.384	52.386
11	31.223	30.662	18	61.283	52.923
12	34.151	34.373			

Taken from "The Examination of School Children." Pyle.

DYNAMOMETRIC DETERMINATION

Strength of Grip.—The dynamometer is used for testing strength of grip.

Table 25.—Norms for Strength of Grip (Smedley)

Age	Boys		Girls	
	Right hand	Left hand	Right hand	Left hand
6	9.21	8.48	8.36	7.74
7	10.74	10.11	9.88	9.24
8	12.41	11.67	11.16	10.48
9	14.34	13.47	12.77	11.97
10	16.52	15.59	14.65	13.72
11	18.85	17.72	16.54	15.52
12	12.24	19.71	18.92	17.78
13	24.44	22.51	21.84	20.39
14	28.42	26.22	24.79	22.92
15	33.39	30.88	27.00	24.92
16	39.37	36.39	28.70	26.56
17	44.74	40.96	29.56	27.43
18	49.28	45.01	29.75	27.66

The results of testing with both the spirometer and the dynamometer are frequently unreliable. To overcome as far as possible the physical discomfort which accompanies the use of the dynamometer it is an advantage to work with groups, so that the element of rivalry may enter in to counter-balance the discomfort.

For tests of endurance with the ergograph see Whipple.

Mrs. Woolley, of Cincinnati, finds that all these tests correlate directly with mental defects, as do Christopher and Smedley (see Whipple).

LENGTH OF LEGS

The legs should be measured from the anterior superior spine of the ilium to the internal malleolus. If there is a difference of more than 1 cm. between them and if the patient does not limp, the shoe of the shorter leg should be built up to compensate for it.

THE HEART. THE PULSE

The physical examinations of 250,000 school children in New York City during the year 1918 showed an incidence of 1.6 per cent. of heart defects.

The causes of organic disease of the heart under the age of 30 are focal infections, usually of the tonsils, teeth or adenoids. The importance of such lesions in relation to the heart is shown by the statistics of Dr. Lambert of Bellevue Hospital, who found that 65 per cent. of their cases of rheumatism showed infected or carious teeth, and 35 per cent. showed infected tonsils: infected teeth apparently producing the higher incidence. Beginning with 1914 there appeared a diminution in both the total number and the ratio to total number of all cardiac lesions entering the hospital.* This improvement he traces to the dental clinics and children's nose and throat clinics, which have been ridding children of etiologic infections. High tenement houses are also given as a cause, though they are not a factor in most American and continental cities.

The relative size of the heart is greater in children than in adults. It is relatively smallest about the seventh year; at this age the heart, which has been relatively larger than the blood vessels, begins to be relatively smaller, and this factor, with others mentioned (p. 922), diminishes the child's vigor at this period.

The weight of the heart at different ages is as follows (Boyd):

TABLE 26

AGE	GRAMS
At birth	20.6
1½ years	44.5
3 years	60.2
5½ years	72.8
10½ years	122.6
17 years	233.7

The anatomical differences of the child's heart as compared with the adult's are:

1. It lies more horizontally in the chest.
2. As the diaphragm is higher, the position of the heart is higher.

The following pulse rates have been found in 1,000 cases (Fischer):

TABLE 27

At birth	130 to 140
First year	115 to 130
Second year	100 to 115
Third year	90 to 100
Seventh year	86 to 96
Fourteenth year	84 to 94

Dr. J. B. Herrick calls attention to a natural arrhythmia occasionally found among normal children at this age, which is characterized by a variation in the pulse brought about by respiration. It may be rapid with inspiration, and slow with expiration, and resemble a pathological condition. He has found that physicians sometimes keep these children in bed for this reason, when the condition is wholly physiologic and should be in the main ignored. Vital capacity has a probable relation. Heart murmurs are not infrequently found in children with normal hearts, the hemic murmur as is well known not being transmitted to the left of the mammary line. The most important general indications of overstrain are dyspnea, cyanosis, edema, palpitation, etc.

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* Connor, Lewis A., Discussion: Heart Disease as a Public Health Problem, Jour. A. M. A., lxxiv, No. 23 (June 5, 1920), p. 1566.

A study has been made of blood pressure and pulse rate in relation to exercise in normal children, which shows that exercise tolerance cannot be determined from the pulse rate as it frequently falls to normal within normal time limits, though there are marked evidences of overstimulation of the heart. Blood pressure is a much more constant indicator. If the heart is overtaxed there is an increased rise, a delayed rise and summit, and prolonged fall.* Research on the physiology of the heart shows that physical work stimulates the activity of the normal heart, as shown by the increase in rate or in strength of beat or both. With this occurs constriction of the splanchnic vessels and the two factors, acting together, increase the blood pressure. This, in turn, augments the flow of blood through the coronary arteries, thus maintaining the nutrition of the stimulated heart. This increase of blood flow develops contractility in the heart muscle fibers and, in this way, produces reserve power. The hearts of normal children have been tested with the following exercises:†

1. Swinging two iron dumb-bells (2, 3, 4, 5, 7 and 10 pounds each) from the floor to the full stretch of arms overhead and back again between the legs at a constant rate of two seconds for each swing, the movements being repeated from 20 to 40 times to increase the amount of work.

2. Stair climbing: Two and four flights of stairs with a total rise of 15 and 30 feet respectively taken in from 10 to 40 seconds.

3. Jumping rope: Rope was jumped 100 times in 100 seconds. The table below indicates the normal range and reactions to these tests:

TABLE 28.—STANDARDIZED TEST EXERCISES

Test exercises	Age in years for standard weight and height	Normal range								
		Simple or mild			Average			Severe or strenuous		
		Number of dumb-bell	Weight, pounds	Swings, times	Number of dumb-bell	Weight, pounds	Swings, times	Number of dumb-bell	Weight, pounds	Swings, times
Dumb-bell test:										
Swinging two iron dumb-bells from the floor to full stretch of arms overhead and backwards between the legs at a constant rate of two seconds for each swing.	6–8	2	3	10	2	3	20	2	3	30
	.....	2	4	10	2	4	20	2	4	30
	8–12	2	4	10	2	4	20	2	4	30
	.....	2	5	10	2	5	20	2	5	30
	12–15	2	5	10	2	5	20	2	5	30
	.....	2	7	10	2	7	20	2	7	30
	.....	2	10	10	2	10	20	2	20	20

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* Barringer, T. B., Jr., Principles Underlying the Treatment of Heart Disease by Exercise, Jour. A. M. A., lxxvii, No. 1 (July 2, 1921), p. 9.

† Exercise Tolerance of Children with Heart Disease, Jour. A. M. A., lxxvi, No. 24 (June 11, 1921), p. 1629.

	Age, years	Number of flights	Rise, feet	Time, seconds	Number of flights	Rise, feet	Time, seconds	Number of flights	Rise, feet	Time, seconds
Staircase test: Stairs taken at a steady climb without rest	6–14	2	15	40	4	30	40	4	30	20

	Reaction of average normal children following test exercises		
	To the mild test exercise	To the average test exercise	To the severe test exercise
Color of face (flushed)	....	+	++
Degree of dyspnea	....	+	++
Degree of fatigue	....	....	+
Rise of systolic blood pressure	10–15 mm.	20–30 mm.	30–40 mm.
Type of systolic curve	Normal	Normal	Normal

Further studies showed that if there were not cardiac insufficiency, 69 per cent. had a normal tolerance for the above standardized test exercises, 29 per cent. had a fair tolerance and 2 per cent. had a poor tolerance.

Diseased hearts in school children can be benefited by proper exercise which can now be guided by the norms. Barringer classified exercise as energetic and mild. In the energetic type the working periods are short and alternated with periods of rest. These exercises should be carefully prescribed, and consist of "exercise with dumb-bells, stair climbing, skipping rope, running in place, hopping, and all calisthenic exercises in which the body trunk is moved widely." After each period the patient rests until blood pressure and pulse return to normal. The periods are repeated from 5 to 10 times at each exercise period, which is generally once in 24 hours.

"The mild form of exercise is one which stimulates the heart activity only moderately over long periods of time as shown by the small increases in blood pressure subsequent to the exercise." Walking, setting up exercises, in which the arms and legs and not the trunk are moved, are recommended.

The first public attempt to relieve the social difficulties of heart patients occurred in New York City in 1912, when a heart clinic was established. Since then other clinics and institutions of like nature have been established elsewhere. Hospital social service workers or nurses in coöperation with the physician in charge combine in following up these cases into their homes where they see that they have proper care, or they find suitable homes for them in the country. They also make special arrangements for them in the school in regard to stair climbing and see that physical defects are removed. Cardiac groups are supplied with a 5 or 10 cent lunch followed by rest of one hour. They continue at school work until 3 o'clock when the work becomes distinctly recreational and vocational. They remain until 4:30 or 5 p.m. Temperature and pulse are recorded every morning so that exercise may be avoided for children if fever is present and a quiet rest room is provided for children with fever or showing unusual fatigue. The social worker instructs the parents, watches the child's nutrition, home recreation, habits, clothing, etc., so as to avoid further strain or infection. The school provides suitable graduated exercise.*

Children with heart disease are not handicapped mentally, it is therefore with their minds that they can earn their bread with least harm to themselves, and they should for that reason be given every opportunity for mental development that will produce practical results. An excellent study of the physiological factors in heart action has been made.

BLOOD PRESSURE

Blood pressure is of relatively little value in children, except as an indication of vigor. Blood pressure findings in children, according to weight, are as follows:

TABLE 29

30– 40 pounds	95
40– 50 pounds	100
50– 60 pounds	107
60– 70 pounds	112
70– 80 pounds	116
80– 90 pounds	122
90–100 pounds	126

Blood pressure as a test of vasomotor efficiency may be of value for delicate children with or without evident heart trouble.

C. Ward Crampton† makes the following statement, in regard to late adolescents which may or may not be significant in children but should be taken into consideration: "In the perfectly normal vigorous male the blood pressure will rise from 8 to 10 mm. of mercury upon assuming the standing position. In one damaged by disease, overwork or unhygienic living, or weakened by inactivity, the blood pressure will fail to rise, and may fall as much as 10 mm. of mercury. The heart rate acts in exactly the opposite fashion, rising in proportion to weakness as much as 45 beats a minute, but only in exceptional cases falling. These two adjustments are independent, one often masking the failure of the other, and both must be considered and balanced. If blood pressure were alone considered, many cases showing a high heart rate would be given a good rating when it should be poor, and *vice versa*."

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* Halsey, R. H., Heart Disease in Children of School Age, Jour. A. M. A., xxvii, No. 9 (Aug. 27, 1921), p. 672.

† Blood Ptosis—A Test of Vasomotor Efficiency, 4th I. C. on School Hygiene, v, p. 555.

Campbell, C. Macfie, "The Rôle Instinct, Motion and Personality in Disorders of the Heart." Jour. A. M. A., Nov. 16, 1918, 71, pp. 1621–1626.

The usual range of the systolic pressure is from +10 to −10; of the heart rate increase from 0 to 44. Upon a statistical balancing of these two series we have a:

TABLE 30.—PERCENTAGE SCALE OF VASOMOTOR TONE
(C. WARD CRAMPTON, M. D.)

Heart rate	Blood pressure										
Increase	Increase					Decrease					
	+10	+8	+6	+4	+2	0	−2	−4	−6	−8	−10
0– 4	100	95	90	85	80	75	70	65	60	55	50
5– 8	95	90	85	80	75	70	65	60	55	50	45
9–12	90	85	80	75	70	65	60	55	50	45	40
13–16	85	80	75	70	65	60	55	50	45	40	35
17–20	80	75	70	65	60	55	50	45	40	35	30
21–24	75	70	65	60	55	50	45	40	35	30	25
25–28	70	65	60	55	50	45	40	35	30	25	20
29–32	65	60	55	50	45	40	35	30	25	20	15
33–36	60	55	50	45	40	35	30	25	20	15	10
37–40	55	50	45	40	35	30	25	20	15	10	5
41–44	50	45	40	35	30	25	20	15	10	5	0

Note: In case of increase in pressure higher than +10, add 5 per cent. to the +10 column for each 2 mm. in excess of 10.

The 100 mark indicates a perfectly efficient working of the vasomotor system under test, the 0 is approximately the point where the average person is unable to maintain the erect posture. The technique of the test is as follows:

The sphygmomanometer is adjusted over the brachial artery and the patient is placed on a comfortable couch with a low pillow. The heart rate is counted by quarter minutes, and a gradually decreasing rate is usually observed. Counting should be continued until two successive quarter minutes are the same. This is multiplied by four and recorded. The systolic pressure is then taken, preferably by auscultation. The patient stands, the heart rate is counted as before until it reaches the "standing normal," when it is recorded, and the blood pressure is then taken. The differences are calculated, and reference is made to the scale. For example: Case L.V., age 17 years, claims to be in good condition at 11:20 a.m., but was coming down with "cold and fever."

	PULSE RATE	BLOOD PRESSURE
Horizontal	68	100
Vertical	104	94
Difference	+36	−6

Percentage 20—very low.

The following is a typical record:

TABLE 31

Time	Pulse rate	Blood pressure	Percentage	Remarks
9:45 a.m.	0	+10	100	Slept well, no exercise.
10:45 a.m.	0	+ 4	85	After lesson in physics, standing.
11:50 a.m.	8	+10	95	After lesson in algebra.
12:24 a.m.	5	+ 6	85	After lesson in French.
1:10 p.m.	6	+ 8	90	After lunch and rest.
2:00 p.m.	14	+ 8	80	After history lesson.
2:35 p.m.	16	+ 4	70	After slow one-mile run.

This shows that one period of work in the physics laboratory (which required continued standing) was more expensive than a slow mile run; it also shows the importance of considering both heart rate and blood pressure. This test has been used to test the amount of relaxation of vaso-tone resulting from various forms of physical exercise, and shows clearly that exercise is expensive in the matter of nervous energy and should be followed by rest and recuperation. It will not test heart lesions, will power, inhibition, or skill, but it does provide a means of making a definite record of an all-important bodily function.

See article on the "Heart," p. 947.

ANEMIA

The formed elements in the blood of children differ from those of adults in number, hemoglobin and in percentage. Red blood corpuscles in infants vary from 4,200,000 to 6,500,000 per cubic millimeter. In later childhood the normal erythrocyte count is from 4,000,000 to 4,500,000. Leukocytes average about 9,000 in children after infancy. Hemoglobin is relatively high at birth, but in later infancy decreases markedly. As the child grows toward the age of school entrance, and afterward, the hemoglobin content gradually increases. Hemoglobin studies of large numbers of children made with a reliable hemoglobinometer such as the Dare are not to be found, but it may be said in general that normal limits are from 60 in early childhood to 80 at the prepubertal period.

The following are the classes of anemia found in children: (*a*) Primary; chlorosis, probably (Fischer, "Diseases of Infancy and Childhood"), leukemia. (*b*) Secondary; Simple anemia, the pseudoleukemic anemia of infancy (von Jaksch), pernicious anemia. Alimentary anemia* may or may not be a primary blood disease.†

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* Kleinschmidt, H., Uber Alimentarie Anämie und ihr Stellung unter den Anämien des Kindes Alters, Jahrb f. Kinderheilkunde, N. F. 83, Heft 8 (Feb. 14, 1916), p. 27; *ibid.* (März, 1916), p. 221.

† For a discussion of the graver blood diseases of children see A. Clodius, Zur Frage der Anämien des Kindesalters, Monatschrift für Kinderheilkinde, Bd. 15, Nr. 2, p. 111.

TABLE 32

	Age	Primary or secondary	Erythrocytes	Leukocytes	Hemoglobin
Simple anemia	All ages	Secondary	Moderately reduced	Normal to 50,000 (acute infectious diseases), depending on cause	Moderately and proportionately reduced
Chlorosis	At or after puberty	Primary	Moderately reduced	Normal or slightly increased	Color index low
Leukemia	All ages	Primary	Greatly reduced	Enormous increase (myelocytes)	Reduced in proportion to erythrocytes
Alimentary anemia or infectious anemia	Under 5½ years	Primary or secondary	Very much reduced. Usually another type in which erythrocytes are increased, poikelocytosis, etc	Slightly increased	Decreased Sometimes color index low
Pernicious anemia	All ages. Rare in childhood	Secondary (probably)	Greatly reduced	Increase slight	Low. Color index high
Pseudoleukemic anemia of infancy (von Jaksch)	Under school age	Secondary	Greatly reduced	Greatly increased	Greatly reduced

Even simple anemia and chlorosis may be accompanied by slight enlargement of the liver or spleen. In splenic leukemia, and in anemia-pseudoleukemia, the spleen is enormously increased in size. It is also much increased in size in pernicious anemia. In alimentary anemia it is usually enlarged in proportion to the severity of the disease.

Etiology.—The causes of anemia are acute infectious diseases, especially typhoid fever, influenza, scarlet fever, measles and whooping cough;* infections of the bronchial tubes and upper respiratory tract; chronic infections (syphilis, tuberculosis, exudative or strumous diathesis, chronic focal infections particularly infected adenoids, tonsils, teeth, etc.); diseases primarily affecting the blood; scurvy, malaria, intestinal parasites (hookworm and other forms of helminthiasis); intoxication from chronic constipation; sensory irritation of the skin (scabies, pediculosis, eczema, chronic urticaria, enuresis). All of these sensory disturbances produce sleeplessness, thus producing anemia, as do pain, worry, masturbation, refractive errors, movies, too much home work, or difficult school work and too late hours on the street. Unhygienic surroundings: lack of sunlight, dampness, overheated rooms, poor ventilation, and food insufficient in the number of calories, insufficient in the content of mineral salts—especially iron and calcium— and insufficient in vitamins (see Nutrition). Children who come to school habitually without breakfast, or who have had a cold breakfast, or who are allowed to drink tea and coffee, or whose food is over-refined, are all in danger of anemia.

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* Schiff, Er., und Matyas, E., Fortlaufende Untersuchungen über die Zahl der roten Blutkörperchen und den Hemoglobin inhalt des Blutes bei Masern, Monatschrift für Kinderheilkunde, Bd. 15, Nr. 2 (1918).

Studies of hemoglobin at the School of Education of the University of Chicago were made in 1912, and a comparative study of the hemoglobin of 100 children in the Jewish Home for the Friendless. The children of the School of Education were from homes of comfort or luxury; the latter group were all from homes of poverty, a number of the mothers being tubercular. In height and weight the well-to-do children were supernormal; in height the poor children were subnormal. Notwithstanding these differences, the children from the Jewish Home averaged 5 per cent. higher in hemoglobin than the children of the School of Education. It was thought that there might be a difference in race. Control tests with Jewish children of the School of Education were therefore made, but it was found that 60 per cent. of Jewish girls and 83 per cent. of Jewish boys in the latter group were below the average of hemoglobin for the Jewish School. On the whole, the difference, therefore, could be attributed only to a difference in food. The well-to-do children were for the most part given bread made of finely bolted flour and other denatured foods, while the children in the Jewish Home were fed on brown bread and other cheap foods which contained large amounts of mineral salts.

Baginski also ascribes the cause of chlorosis to the change in the relative size of the heart and blood vessels at the age of puberty. Clodius* traces the cause of alimentary anemia, and perhaps that of pseudoleukemic anemia of infancy to fundamental constitutional alteration of the fetus. He has found a significant connection in the above diseases between both twins and premature birth.

Symptoms.—Anemic children show a low per cent. of hemoglobin, and pale mucous membranes. Usually the skin is also pale, but as children approach puberty, and later in adolescence, there may be high color of the cheeks due to a lack of tone of the vasodilators. Anemic children are tired and listless, unable to concentrate, irritable and sometimes short of breath; they have headaches, and poor or capricious appetite; they are frequently constipated; they manifest a need for sleep, or they may be over-wakeful. Children with simple anemia are usually malnourished, but the more severe anemias are sometimes accompanied by a superficial appearance of being well nourished.

Prognosis.—This depends upon the cause. In constitutional anemias only, the prognosis is grave.

Treatment.—Remove the cause, whether it be a source of chronic infection, intestinal parasites, constipation, sensory irritation, lack of sufficient sleep, overstrain in school, poor sanitation or improper food.

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* *Ibid.*

Pretubercular and open-window schools which provide half the food calories, rest, open air, and freedom from the worry incident to school overstrain are the best means of overcoming anemia. Medicinal iron in the form of the saccharated carbonate, or the iodide, or with strychnine and quinine as an elixir are all beneficial. They should always be given with foods containing calcium and iron, as medicinal iron seems only to work in the presence of food iron (see Nutrition).

THE TEETH

A tooth consists of a crown and root joined by a narrow portion called the neck. The crown is exposed; the root is covered by cementum, a substance harder than dentin, resembling bone, which is directly in contact with the peridental membrane, this in turn holding it to the alveolar process. The outer covering of the crown is enamel, an inorganic substance which is very hard and resistant. Underneath it lies the dentin—a calcified connective tissue—which forms the body of the tooth, and carries in its substance innumerable sensory fibrils which, if exposed, convey impressions of pain due to contact with cold, heat, sweets, etc. In the center of the tooth is a chamber filled with living matter, including the blood vessels and nerves whose terminals ramify through the dentin.

Teeth of the first dentition are irrupted to the end of the second year. It is important that they should be preserved in good condition until their work is done, *i.e.*, until the appearance of the teeth of the second period. As soon as the teeth are irrupted they are attacked by bacteria, and as a result we have the following conditions to combat: green stain, caries, toothache, pyorrhea, alveolar abscesses, and finally complete loss.

Etiology.—The mouth is an excellent incubator for microbes, as it affords darkness, moisture, heat and food. Many varieties of bacteria have been found, but the predominating organisms are the streptococcus hemolyticus in acute alveolar abscesses, and the streptococcus viridans in chronic alveolitis. The latter far outnumber the former. Gilmer cites the occurrence of alveolar abscesses in epidemics, and suggests that they may or may not be related to epidemics of inflammation of the nose and throat. It is well known that the pneumococcus is frequently found in alveolar abscesses.* The bacteria do not affect the teeth directly, but by decomposing saliva and ingested sugars they are able to overcome the resistance of enamel and dentin. It is quite well established that the hardness or softness of teeth is not of especial importance in determining their predisposition to decay; decay depends rather upon the state of acidity of the blood and the numbers of bacterial antagonists.

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* Billings, Frank, Mouth Infection as a Source of Systemic Disease, Jour. A. M. A., lxiii, No. 23 (Dec. 5, 1914), p. 2024; and Gilmer, Thomas L., A Study of the Bacteriology of Alveolar Abscess and Infected Root Canals, Jour. A. M. A., lxiii, No. 23 (Dec. 5, 1914), p. 2023.

The Carious Process.—The first step is the formation of the "bacterial plaque," which is composed of mucin (precipitated on the surface of the tooth by lactic acid), of bacteria, and of food debris. If a solution of 7 per cent. iodine is painted over the surface of the tooth these plaques appear as small dark spots. Decay occurs on surfaces and in crevices where there is little friction and in places difficult to reach. In some localities in the mouth, notably near the openings of the salivary ducts, there are large accretions of mineral salts mixed with mucin and bacterial debris known as *tartar*.

Green stain is found at the gum margin and is due to the irritation at this point of putrefactive bacteria in combination with mucin and the coloring matter of blood.

Pyorrhea, or gum abscesses, involves the peridental membrane at the neck of the tooth, or the gingival margin as it is called. This condition is the result of irritating and neglected deposits of tartar, of an unhealthy condition produced by poor mouth hygiene, and by irritation which results if there is too little healthy vigorous use of the jaws in chewing.

Alveolar abscesses occur at the roots of the teeth and are either acute or chronic. When acute they are accompanied by symptoms of heat, swelling and pain, with the formation of pus which usually discharges, but may subside and become caseous.

Toothache occurs as a rule simultaneously with decay and alveolar abscesses, and is due to the irritation of the sensitive fibrils radiating through the dentin. The carious process also advances toward the pulp by means of bacteria that travel onward along these same fibrillar lines, eventually reaching the pulp over this route.

The early loss of teeth, under the twelfth year, is serious, as their presence is important in the development of a larger jaw and proper occlusion.

Irregularities of the teeth may be manifested either as departures from the normal in the shape of the individual tooth, or irregularities in position. Of the former we have eroded teeth as the result of rickets, or other early nutritional disturbance,* and pegged and Hutchinson's teeth as the result of syphilis. Of irregularities of position we have conditions due to overcrowding and malocclusion. Overcrowding may be rectified by gradual artificial enlargement of the jaw. Occlusion of the teeth is the relationship of their biting surfaces when the mandible is in the position of the resting bite. Normally the upper incisors and canines, which are outside the lower, snugly overhang them. The biting surfaces of the bicuspids and molars are not even and flat, but so provided with corresponding elevations, or cusps, and intervening depressions that when the jaws are properly placed in relation to each other the cusps of one exactly fit into the depressions of the other. This gives 100 sliding surfaces which with the natural scissor-like motion of the jaws cut or grind the food.* Malocclusion is most commonly produced by misplaced irruption of the six-year molars, the cusps of the upper molars lying in front of their normal position. At first this is not apparent, but a marked deformity appears by the age of eight or nine, and then rapidly increases until the age of twelve. In malocclusion of this type the upper front incisors protrude at least the distance of a molar cusp in front of their normal position, and the lower lip does not close over the upper front incisors, or meet the upper lip, therefore the child breathes through his mouth. A nasal cold occurring shortly after the irruption of the six-year molars may, by means of temporary mouth breathing, produce malocclusion.† The medical survey of rural schools made in Porter County‡ shows that 4.8 per cent. of the school children examined had serious occlusal defects. Fones makes the statement that 98 per cent. of all children examined in the public schools of Bridgeport in the last five years have had more or less malocclusion.

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*Abt, I. A., and Mortimer, Frank, Rachitic Erosions of the Permanent Teeth Associated with Lamellar Cataract, Fifty-ninth Annual Session of the American Medical Association.

The number of dental defects among school children is variously estimated from 33 to 53 per cent. (table of defects). Fones§ states that children of the first five grades in the public school average not less than seven good-sized cavities, and that 10 per cent. of these are fistulous.

The *results* of defective teeth are both multiform and serious. Malocclusion is produced by and produces mouth breathing, a narrow upper arch, carious teeth, and mental retardation. Painful teeth and missing teeth, whether in child or adult, interfere with mastication. In children this is doubly serious, as feeble movements of the jaw in chewing not only interfere with the proper preparation of food, but with the proper development of the skull bones, and especially of the jaws. Purulent conditions of the gums or alveolar processes are said to produce 20 per cent. of all diseases. The intimate relation of pyorrhea and osteoclasia to systemic disease has been so thoroughly and brilliantly brought before both the medical and lay public that it hardly needs further emphasis here. The augmentation of virulency by culture conditions in unhygienic mouths is emphasized by Rosenow** and is a matter of the greatest importance. The relation of diseased mouths to epidemiology is well brought out by Fones,†† showing a favorable difference which he attributes to the improvement in the condition of the mouths of the school children after the introduction of school hygienists in the schools of Bridgeport.

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* Fones, Alfred C., "Mouth Hygiene."

† Noyes, Frederick B., Jour. A. M. A., Nov. 18, 1922, p. 1760.

‡ Public Health Bulletin, No. 77 (June, 1916). Quoted by Woodbury, William R., The Petersham Plan, Boston Medical and Surgical Journal, clxxvii, No. 24 (Dec. 13, 1917), p. 834.

§ Report of Five Years of Mouth Hygiene in the Public Schools of Bridgeport, Connecticut, The Dental Cosmos (July, 1919).

** Rosenow, E. C., Transmutations Within the Streptococcus Pneumococcus Group, Jour. Infect. Diseases, xiv, No. 1 (Jan., 1914), p. 1.

†† Dental Cosmos (July, 1919).

TABLE 44.—MORTALITY RATES BEFORE AND AFTER THE ADVENT OF SCHOOL HYGIENISTS

	1914, PER CENT.	1918, PER CENT.
Diphtheria	36.6	18.7
Measles	20.0	4.1
Scarlet fever	14.1	0.5

Fones has also studied the relation of retardation to defective teeth and finds that it is reduced 50 per cent. The following table is sufficient:

TABLE 45.—PUPILS 14 YEARS OF AGE AND OVER

Grades	I	II	III	IV	V	VI	
September, 1912	13	17	58	107	169	212	4.0 per cent. of elementary pupils.
November, 1918	0	0	11	35	109	155	1.5 per cent. of elementary pupils.

A study of children in Cleveland* showed that 97 per cent. had carious teeth. In a school of 846 children, special attention was given to the mouths of 27 children showing the highest number of dental defects, with the result that with the lapse of a short time an increase of 99 per cent. school work efficiency was shown. Johnson has demonstrated that two badly decayed molars will retard a child six months in school during the first eight grades. In New York City 67,000 children failed to be promoted because of absence; 80 per cent. of this was believed to be due to defective teeth. Fones believes that the dental work done in the Bridgeport schools has raised the mental status as a whole 15 per cent.

Children often develop great irritability and other serious nervous manifestations as the result of painful teeth. There is no longer the slightest doubt concerning the relation of alveolar abscesses and pyorrhea to chorea, and it is possible that the irritation produced by impaction and pain may augment the severity and number of epileptic attacks (William R. Woodbury).

Acne is sometimes the result of mouth infections, and doubtless many cases of infected tonsils are secondary to alveolar abscesses.

Diagnosis.—The *x*-ray is of vital importance in determining the presence or absence of alveolar abscesses. Many abscesses dry, leaving caseous foci containing live bacteria about the roots of the teeth. They are in a latent condition and cause neither pain nor tenderness nor insecurity. As their systemic results, however, may also be very serious, their presence should be investigated with the *x*-ray.†

The differentiation of toothache when it concerns the pulp is important, as it may be possible to save the nerve.

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* Johnson, Earle E., Effects of Decayed Teeth Upon a Child's Progress in School, The Dental Cosmos (April, 1918), p. 293.

† For description of films, etc., see Fones, "Mouth Hygiene."

Infection of Pulp	Dying Pulp
Sensitive to touch	Sensitive to touch
Sudden severe pain	Severe toothache
Pain increased by heat	Pain increased by heat and cold
Relieved by cold	Pain ceases suddenly

If there is infection of the pulp, the pulp should be opened at once, therefore it is important that the child should have immediate expert dental care, as a delay of 24 hours is serious. While a dying pulp requires immediate dental service, it may be deferred without anything worse than the suffering of the patient.

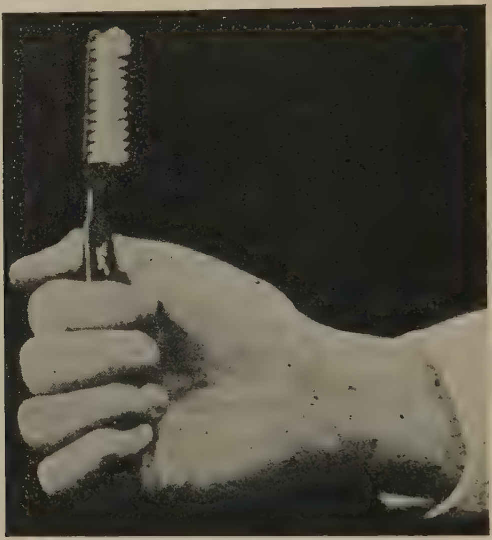

Fig. 247.—Correct method of holding the brush. (Fone's "Mouth Hygiene.")

Treatment.—At the beginning of the school year the teeth of all school children between first and fifth grades are inspected by school dentists. Notes are made at this time of defective teeth and malocclusion, and kept on file. At once the dental hygienists begin toothbrush drills and demonstrations of the use of dental floss, which are continued until the method is perfected (Figs. 247, 248). Dental hygienists spend part of each day polishing teeth, as the roughened areas more quickly succumb to decay. Cavities of the six-year molars are given especial attention. Children with these conditions are sent to the office of the school dentist. Parents are advised of other defects and generally respond to the information given.

Brushing is urged four times a day with the use of a soap and chalk mixture, either in the form of paste or powder (see figure). Lime water made with coarse lime (rough plaster) dissolves the mucin, and is very essential as a mouth wash in preventing the formation of the bacterial plaque. A solution of soda or common salt in water, in the proportion of one-fourth teaspoonful to a small cup of water, is an excellent substitute.

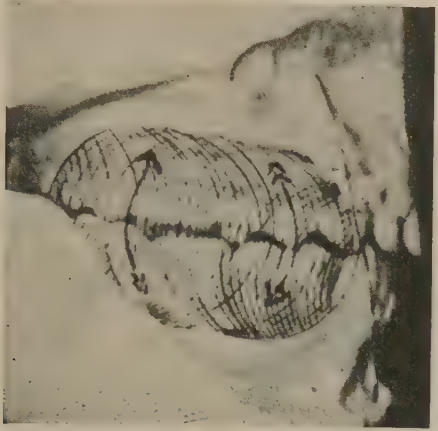

FIG. 248.—Correct movement of brush. (Fone's "Mouth Hygiene.")

TYPICAL TOOTH-BRUSH DRILL

After the form advised by the Second District Dental Association, New York

Two or three children, provided with tooth brushes, dentifrice, cups, water and a basin, should demonstrate this drill before the class. Every member of the class should follow the leaders in pantomime.

Attention! (All in line, elbows close to side, with brushes in right hand and cups in left.)

1. *Ready*—Dip!
2. *Outside Surfaces.* (Brush inserted under cheek, teeth closed. Brush gums as well as teeth.) Circular motion. (See Fig. 248.)
   Left Side—Ready—Count 1 to 16. Dip.
   Right Side—Ready—Count 1 to 16. Dip.
   Front Side—Ready—Count 1 to 16. Dip.
3. *Inside Surfaces.* (Mouth wide open, straight motion front to back.)
   Upper Left Side—Ready—Count 1 to 16. Dip.
   Right Side—Ready—Count 1 to 16. Dip.
   Front Side—Ready—Count 1 to 16. Dip.
   Lower Left Side—Ready—Count 1 to 16. Dip.
   Right Side—Ready—Count 1 to 16. Dip.
   Front Side—Ready—Count 1 to 16. Dip.
4. *Chewing Surfaces* (scrubbing vigorously).
   Upper Left Side—Ready—Count 1 to 16. Dip.
   Right Side—Ready—Count 1 to 16. Dip.
   Lower Left Side—Ready—Count 1 to 16. Dip.
   Right Side—Ready—Count 1 to 16. Dip.
5. Empty cups and refill them—Ready—Count 1 to 16.
6. Rinse mouth—Ready—Count 1 to 16.
7. Rinse brush—Ready—Count 1 to 16.
   (Shaking off excess of water over basin.)

N.B.—Counting by leader should be rather brisk but even and should allow plenty of time for dipping and shaking of the brushes.

Materials.

1. Tooth brushes (brought to school in envelopes made by leaders).
2. Dentifrice.
3. Individual cups (paper preferably), made by the leaders at home, to be half filled with water by monitor.
4. One pitcher of water.
5. One tin basin.

From Course of Study and Tentative Syllabus on Hygiene for Elementary Schools, Board of Education, New York City (June 14, 1916).

Any community desiring the establishment of dental work in its schools will find that the first step is a demonstration of the need. Even though the community be isolated, it is usually possible to secure the services of some dentist for a preliminary survey of the mouths of the school children. This can be followed up by literature and the Dental Council of Massachusetts has prepared a standard lecture on mouth hygiene entitled "The Care and Use of the Human Mouth," which can be secured with films for a nominal fee. The Massachusetts Council is also standardizing a dental clinic including rules of organization, equipment, operative procedures, and general management. This Council may be reached through the Forsyth Dental Infirmary for Children, 140 The Fenway, Boston. Alfred S. Fone, "Mouth Hygiene," gives details of organization, of the training of dental hygienists, and practical and complete discussion of all phases of mouth abnormalities.

The Dental Welfare Foundation of Pittsburgh, U. S. A., is publishing with the approval of the National Dental Association a series of short Health Talks on facts related to teeth which they are distributing on postal cards to teachers.

GLANDS

Lymphoid tissue is found wherever the body requires defenses. Notable accumulations occur in the throat, near the appendix, in the mediastinum and mesentery, and externally in the neck, axillæ and inguinal regions. In childhood, masses of lymphoid tissue are large because the organism carries on a rapid metabolism, and also because they are necessary in building up immunity. The metabolism theory is perhaps best illustrated by the axillary and inguinal glands which drain the mammary and pelvic reproductive organs and do not develop until puberty, when activity of these organs begins. The protection theory has been established by the fact that in localities where lymphoid tissue is abundant and absorption is occurring rapidly, there is the most extensive and various intestinal flora. If smear and culture preparations are made at intervals along the alimentary canal it is found that the number of bacteria normally present and the amount of lymphoid tissue parallel each other. Added to this is a fact of universal observation that whereas immunity is very low in infancy, it gradually increases with the years, while coincidently, as has just been said, lymphoid tissue decreases.

The most important lymphatic structures in the body are the tonsils. It is here that microbes gain their first point of entrance, and from here by connection with the deeper lymphatics the microbes are passed on. Grober injected the tonsils of living dogs with Chinese black paint and on post-mortem found the ink in the tonsils and cervical glands, as well as in the supra-clavicular, bronchial, cardiac and mediastinal glands. Other experiments with inorganic powders show that such substances, if blown into the nasal cavities, are carried into the tonsils. Thus it is argued that germ laden-lymph from the nose and throat passes into the systemic circulation. It is known that organisms and toxins "from the tonsils pass into the anterior deep cervical glands of the neck." Enlargement of the lymphatic gland located just outside and below the tonsil (often called the tonsillar lymphatic gland) is usually due to disease of the tonsil, or infection coming through the tonsil. Toxins, on the other hand, coming from the retropharyngeal lymphatics pass into the posterior and anterior cervical glands of the neck, so that inflammation of the adenoids or pharynx causes enlargement of the cervical glands just back of the sterno-cleido-mastoid muscle, and may occasionally cause enlargement of the anterior chain. It has been shown that if the adenoids are removed, and the tonsils thoroughly enucleated, about 35 per cent. of the enlarged glands disappear, 55 per cent. become very nearly normal, and 10 per cent. persist. The persistent glands are, as a rule, due to infection by the tubercle bacillus. The firm structure of the capsule of this organism makes it resistant to external forces and allows it not only to retain its vitality while in the tonsillar tissue, but sometimes causes the destruction of this tissue. On the other hand, it often leaves the tonsillar tissue unscathed, passing through it into the cervical or mediastinal glands, there to develop activity with organic changes. Most of this infection is derived from milk and causes very little pulmonary disturbance. If cervical adenitis is bilateral it is usually due to tuberculosis, to syphilis, Hodgkin's disease, or blood diseases, and the condition is chronic. Acute enlargement is not tubercular.*

THYROID GLAND

It is sometimes very difficult to find the thyroid gland in children, as the lobes may be so close to the trachea that they cannot be palpated. Their function is of the greatest importance, however; a fact manifested both by a lack of functioning tissue, as in myxedema and cretinism, and also by an increase of thyroid secretion, as in hyperthyroidism. In either case, there is a profound alteration in the output of general cell energy expressed by a great change in body growth and mental development, the neutralization of toxic substitutes and resistance of invaders and the effect upon the pulse rate, blood pressure and temperature, control of protein and calcium metabolism and of sugar and fat, especially at the periods of second dentition, of puberty, menstruation and the menopause. These changes are due "to the complementary action of colloid on intracellular metabolism."*

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* See Good, R. H., Why Are the Tonsils and Lymphatics of the Nose and Throat Responsible for so Many Systemic Diseases? Illinois Medical Journal (May, 1918); and Davis, D. J., The Tonsil in Relation to Infectious Processes, Jour. A. M. A., lxxiv, No. 5 (Jan. 31, 1920), p. 317.

The thyroid gland owes its activity to an iodine-containing protein called thyreoglobulin, which forms one-fourth to one-half of its dry weight. It is the sole active constituent of the colloid of this gland. If thyreoglobulin is decomposed by boiling it with sulphuric acid, a stable substance is formed called thyroidin, which contains 14.5 per cent. of iodin. Thyroxin, another stable substance, is isolated from the thyroid gland after alkaline hydrolysis, and contains 60 per cent. of iodin.†

Iodin is essential for human activity. The amount of iodin varies directly with the amount of colloid present, and seems to have a specific affinity for it.‡

Etiology of Thyroid Disturbance.—(1) Defective or improper food supply, especially a lack of iodine-containing vegetables.

2. Residence in unsanitary surroundings; the incidence among the poor is higher than that among the rich.

3. (*a*) Infectious conditions: acute infectious diseases—measles, mumps, scarlet fever, pertussis, acute tuberculosis; chronic infectious diseases—tuberculosis, secondary syphilis; circulatory diseases—helminthiasis, etc.

(*b*) Constipation and intestinal stasis and toxemia.

4. Psychic causes (fright, grief, worry).§ In very unusual cases hyperthyroidism occurs in school children, and the symptoms are increased by physical training and worry about school activities. Some later investigators take issue with this.

5. Consanguinity and heredity.

The age incidence of 642 strumous boys and girls is shown in the following table of Demme, Jahresbericht des Berner Kinderspitals, 1879:

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* Wells, H. G., "Pathological Chemistry." F. C. Kendall, The Chemical Identification of the Active Constituent of the Thyroid with a Discussion of Its Physiological Function, Bulletin Chicago Medical Society (Oct. 11, 1919).

† Wells, *ibid.*, and Kendall, E. C., The Active Constituent of the Thyroid, Jour. A. M. A., lxxi, No. 11 (Sept. 14, 1918), p. 871; Kendall, E. C., On the Crystalline Compound Containing Iodin Which Occurs in the Thyroid, Endocrinology, i (1917), p. 153.

‡ Marine, David, On the Occurrence and Physiological Nature of Glandular Hyperplasia of the Thyroid (Dog and Sheep), together with Remarks on Important Clinical (Human) Problems, Johns Hopkins Bulletin No. 198 (Sept., 1907).

§ Cannon, W. B., Results of Recent Studies on Ductless Glands, Jour. A. M. A., lxvii, No. 31 (Nov. 18, 1916), p. 1483; and Mackenzie, Hector, Bradshaw Lecture on Exophthalmic Goiter, Lancet, i (Nov. 11, 1916), p. 300. Quoted in Practical Medicine Series (1917).

TABLE 33

37	up to 1 month
59	from 2 to 12 months
35	from 12 to 48 months
83	from 4 to 7 years
94	from 8 to 10 years
150	from 11 to 13 years
184	from 14 to 15 years

Boys and girls are equally affected to puberty; after this period, the number of girls affected is very much greater than that of boys.

Locality is a very important factor. Hot countries, and countries where there is poor drainage and a dense population, show a high incidence. India is said to have 5,000,000 cases of goiter; on the other hand, in large sections of the United States free from any known cause, and in small isolated sections of Switzerland, goiters occur in a large proportion of the female inhabitants.

It is said that water containing a large amount of calcium is a predisposing factor, as it throws an added strain upon the thyroid gland which partly controls calcium metabolism. It is possible also that the iodin content of drinking water has to do with the subject.*

Goiter is congenital or acquired, sporadic, endemic, or epidemic.

Types of Goiter.—

1. Congestion, which is temporary.

2. Thyroiditis, an acute inflammatory condition, which is very rare.

3. Simple colloidal goiter. This is very unusual in early childhood, developing before and after puberty. The development is apparently vicarious—an attempt to supply necessary iodin by means of the hypertrophy of iodin-elaborating structures.

4. Hyperplastic goiter is a physiologic reaction to a deficiency (iodin) and is a condition of cellular hyperactivity which usually precedes colloidal goiter. The cells are increased in the effort to compensate for the lack of iodin, and the colloid is decreased to the same extent.

5. Toxic adenoma, or simple toxic goiter, occurs just before or following puberty with disturbed menstruation, and is due to an overproduction of thyroxin, resulting in loss of weight, notwithstanding a good appetite. There is the sensation of body heat, excessive sweating, and a rapid pulse, which, unlike that of the purely nervous pulse, is rapid with the first pulse beats of the examination. The rate increases with exertion. Exophthalmus in toxic adenoma is absent.

6. Exophthalmic goiter is not due to the over-elaboration of thyroxin, but is probably due to a chemical complex based upon thyroxin, which is not thoroughly understood. The symptoms are like those of toxic goiter, to which is added exophthalmus, tremor, diarrhea, flushing of the skin, and marked increase in basal metabolism which causes considerable loss in weight. This is rare in children.

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* Crile, G. W., Foreword to Bulletin 299, Ohio Agricultural Experiment Station, Wooster, Ohio (June, 1916). On the Iodin Content of Foods, by Forbes, E. B., Beele, F. M., Fritz, C. M., Morgan, L. E. and Rhuge, S. N.

7. Myxedema is due to an atrophy of the thyroid gland in previously healthy children, and results in a dough-like, pasty swelling of the skin which does not pit on pressure, in a loss of perspiration, falling of the hair, and in stunted growth both physical and mental.

8. Cretinism is congenital myxedema, with or without atrophy of the thyroid gland. Most cases of endemic cretinism after the third year of life develop large goiters, and sometimes the appearance of these goiters is attended with improvement. On the whole, the symptoms of cretinism are those of exaggerated myxedema and dwarfism, with defective development of the bony skeleton, the teeth and the genitalia, almost always involving a very low type of mental development. They are frequently deaf mutes.

Basal metabolism (see Nutrition, p. 931) is profoundly affected by the condition of the thyroid gland. There is an equilibrium which exists between the secretion of the gland and the tissues. The usual variation is expressed in a difference of 10+ or 10−. Somewhat greater degrees than this, however, may be regarded as normal. The threshold of actual disturbance would certainly be indicated by basal metabolism below 10 in cretinism and myxedema. Cretins usually have a basal metabolism of −40. Basal metabolism of 20 or over may be regarded as an indication of toxic adenoma or exophthalmic goiter. Pilocarpin and adrenalin are also used to discover indications of hyperthyroidism.

Epidemic goiter occurs sometimes among susceptible newcomers, more often in school children. This is true in many localities in the United States. Many cases are cited of several members of nongoitrous families developing large goiters within six weeks after settling in new localities.

McCarrison* states that the *incubation period* of experimental goiter is from 13 to 15 days.

The epidemic goiter is always soft, though there may be some difference in the size of the lobes. There is spontaneous recovery in about 9 per cent. and incipient goiter frequently disappears if the child leaves the community in which it developed, though the enlargement usually persists. Ordinarily it tends to grow larger in the spring, and to disappear in the autumn, and each time there is a slight permanent increase in size.

Tests which are used now to differentiate the degree of toxicity are basal metabolism estimations,† tests for sugar tolerance and epinephrin tests.‡

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* McCarrison, Robert "The Thyroid Gland."

† DuBois, E. F., The Respiration Calorimeter in Clinical Medicine, Amer. Jour. Med. Sciences (June, 1916), abstracted in Practical Medical Series, i (1917).

‡ These are well described by Smith, Fred M., Studies in Hyperthyroidism, Jour. A. M. A., lxxiii, No. 24 (Dec. 13, 1919), p. 1828; by Means, J. H. and Aub, J. C., The Basal Metabolism in Hypo-thyroidism, Archives of Internal Medicine, xxiv, p. 404; by McCaskey, G. W., Basal Metabolism Determinations in General Internal Diagnosis, etc., Jour. A. M. A., lxxiv, No. 14 (April 3, 1920), p. 927; by Woodbury, Malcolm S., A Comparison of Methods for Determining Thyro-toxisosis, Jour. A. M. A., lxxiv, No. 15 (April 10, 1920), p. 997.

Differentiation from Mongolism.—Cretinism is sometimes called "mongoloid idiocy." It should never be confused with mongolism, in which there is probably an etiological difference and in which the skeletal changes are far less marked, the mental condition less sluggish and the disposition irritable; from *infantilism*, in which the skin is not abnormal in color, nor the tongue nor other tissues of the face changed. There is, however, decided mental retardation, and a lack of development of the genitalia in both conditions.

Treatment.—Efficient prophylaxis may be instituted either by removal from localities where goiter is endemic, or by the semi-annual use for a period of two to three weeks of 1 c.c. daily of the syrup of hydriodic acid, or Syr. ferrous iodid in the same dosage. Kimball and Marine* experimented with 4415 girls to see if goiter formation could be prevented. Not a single pupil in whom the thyroid was normal the preceding year and who took iodin showed any enlargement, while in those not taking iodin 26 per cent. showed definitely enlarged thyroids. One-third of the small goiters disappeared, and one-third moderate-sized goiters showed a decrease of 2 cm. or more. There were no bad results. Roux advocates the prophylactic use of a crystal of metallic iodin imbedded in wax or spermaceti suspended like a locket from the neck.† Roux says that none of these methods will prove advantageous except at the incipiency of the disease and in hyperplastic goiters. Goiters that are cystic or nodular and diffuse follicular colloid goiters are not benefited.

Care must be taken to avoid an excess of iodin fumes, as serious results have followed, especially if there is any pulmonary disturbance present.‡

Soft or boiled water should be used. Foods that contain larger amounts of iodin may be tried, such as sea foods, especially shrimps, crabs, lobster, smoked herring and fresh salmon, some vegetables, particularly green peas, green beans, bananas, tomatoes, garlic and cabbage.§ Meat should be eaten not more than once a day. It is also important to remember that patients with excessive metabolism require a much larger quantity of food.

Ordinary goiter may be treated by the administration of iodin internally in combination with iodide of potassium or sodium, as in Lugol's solution—15 to 20 drops a day adult dosage. Potassium iodide ointment may be used externally. Thyroid extract, on acount of its iodin content, may also be used, beginning with ½-grain doses, and increasing gradually to 6 grains daily. Children taking iodin in any such form must be constantly watched for symptoms of intolerance, which are the following: loss of flesh and strength, fever, tachycardia, nausea, insomnia, restlessness and excessive perspiration. Favorable results of iodin treatment are usually seen within a month, if they occur at all. Thyroxin is advised by Kendall in 1/180-grain doses, because it is a stable substance and can be exactly administered. Great care should be taken to relieve constipation.

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* The Prevention of Simple Goiter in Man, Jour. Lab. and Clin. Med., iii (1917), p. 40.

† "A propos du Goître," Correspondenz-Blatt Schiweizer Aerzte, xliv (1918), p. 369; also Rapport (sur le goitré) *ibid.*, 1917, xlvii, p. 1655.

‡ Luckhardt, A. B., Koch, F. C., Schroeder, W. F. and Weiland, A. H., The Physiological Action of Fumes of Iodin, Jour. Pharmacol. and Exper. Therap., xv (Mar., 1920), p. 1.

§ Editorial: Iodin Content of Foods, Jour. A. M. A., lxvii, No. 21 (Nov. 18, 1916), p. 1526, and Friedenwald Ruhrah, "Diet in Health and Disease."

Cretinism can be partially cured by thyroxin or by thyroid extract, but it must be given continuously. After the myxedema has appeared, body weight is a safe index for dosage in children.

Roentgen-ray is probably the best non-operative treatment for exophthalmic goiter, directed not only upon the thyroid gland but on the thymus as well.* Radium is also used.

POSTURE

As a promoter of health, posture is the most vital subject in physical education. Without a knowledge of the meaning of correct posture, gymnastics, work with apparatus, and some plays and games may do much more harm than good. "It requires perfect adjustment, weight distribution and balance of different parts of the body. It represents the economical distribution of muscular tension, even balance of muscular tone, equalized pressure on the surfaces of joints, and minimum tension on fibrous structures, and it is good for the internal organs† as regards room distribution, relative position, and natural support."‡

Correct fundamental position viewed from the front should be bilaterally symmetrical, the weight equally divided between the feet, the spinal column straight and vertical, hips and shoulders at the same height on each side and equally distant from the spine. Viewed from the side, the general line of the body should be straight from head to heel with inclination forward at such an angle as will bring the center of gravity of the body, which is well forward in the region of the hips, over the balls of the feet. The spinal column should exhibit three normal curves: cervical, dorsal, and lumbar. The poise is tested by rising on the toes. If one has to sway forward or backward before rising, the weight is not over the balls of the feet.§

The vertical line test which is used now in class work generally is a line dropped from the front of the ear through the anterior part of the shoulder and through the greater trochanter to the forward part of the foot at any point from the middle of the arch to the ball of the foot. This line parallels the long axis of the neck and head taken together and the long axis of the trunk of the body.**

Faults of posture; seen from the side:

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* Fisher, J. F., "Ugeske f. Laeger" (Oct. 5, 1916), quoted in Practical Medical Series, i (1917).

† See Goldthwait, Joel E., "The Relation of Posture to Human Efficiency and the Influence of Poise upon the Support and Function of the Viscera."

‡ Skärstrom, "Educational Gymnastics."

§ Bowen, "Physical Training."

** Bancroft, Jessie, "The Posture of School Children."

(*a*) Weight poised too far back (*b*) Hips and abdomen too far forward (*c*) Head too far forward (*d*) Arms and hands too far forward (*e*) Exaggerated lumbar curve or lordosis	These cause	Flattened chest. Diminished breathing. Organs of body crowded and hindered in function. Ptosis.

Seen from the front or rear:

(*a*) Weight not evenly divided (*b*) Uneven hips or shoulders (*c*) Head held to one side	These cause	Lateral curvature of the spine which lessens its supporting power. Pressure upon spinal nerves, and pain (Bowen).

Teachers of physical education and children under their direction will be stimulated to effort by using the Mosher-Lesley schematograph which records posture outlines of the body. It can be obtained from the American Posture Standards Company, 1 Madison Avenue, New York City, N. Y.

Three stages of poor posture:

1. Usually stands correctly—occasional lapses on account of occupation.
2. Habitual stage—good posture feels unnatural, but he can assume it.
3. Structural stage—muscles and bones changed. Cannot correct entirely (Bowen).

Round shoulders are a conspicuous part of poor posture, and are primarily due to a forward position of the head, with a weakness of the sternomastoid and scaleni muscles, which hold the head up in good posture. As a result, the convexity of the dorsal curve is increased with protrusion backward of the scapulæ. The concavity of the lumbar curve is also increased and, as a consequence, the abdomen protrudes. Flat feet often co-exist; children with this condition are generally delicate and clumsy.

Cases are flexible or functional and resistant or structural. If resistant, a child will exhibit a hollow back in the lumbar curve when told to put his arms up in the air in the standing position. The abdomen will protrude because the soft parts between the chest and arms have become contracted and do not permit free movement.*

From the examination of 200,000 children in the New York Schools, Miss Bancroft estimates that 80 per cent. of normal children have anteroposterior faults of posture that need correction, and 25 to 50 per cent. have scoliosis. She also estimates that of the six hours spent in the sixth and seventh grades, 85 per cent. is spent in poor posture. Of the school time, 10 per cent. is spent in the standing position, 80 per cent. sitting. Of the standing time, the larger part is devoted to carrying books and to manual training. Of the sitting time, 4 per cent. only is characterized by good posture. This is the time taken for singing, and when called to the position of attention. For the most part, study periods, writing, drawing, construction work, lounging, etc., are characterized by poor posture.

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* Lovett, "Lateral Curvature of the Spine and Round Shoulders."

Causes of Poor Posture:

Gravitation.
Fatigue and muscular weakness of the supporting muscles.
Excessive recent growth or rapid changes in bodily proportion during growth.
Pelvic obliquity from shortened leg and standing on one foot.
Flat foot.
Deformities from organic nervous diseases involving the chest.
Impaired, especially unequal, hearing.
Impaired, especially unequal, vision.
Improper school room furniture.
Improper school room lighting.
Improper clothing.
Occupation or habit producing unequal development of the shoulder girdle muscles; stretching of the posterior group, shortening of the anterior group.

(*a*) Writing and other manual activities.
(*b*) Carrying books or other heavy burdens either on the arm or by the hand.

Miss Jessie Bancroft has created a standard whereby teachers may grade children according to their posture. Three phases are to be noted by the teacher:

1. Standing posture.
2. Maintenance of good posture while walking or marching.
3. Maintenance of good posture during corrective exercises.

Children, at command, stand by their desks, and are inspected from the side. Those in poor posture are told to be seated. The others then form in line and march around the room. Those who drop into poor posture are again eliminated. Correction work is then given, further elimination following. The class is then divided into good and poor sections.

In February of the first year when this method was originated,* only 40 per cent. of the 200,000 school children in New York, who were tested, could pass the test. In the following June, 85 per cent. passed it. The efficiency of the method lies in the fact that it stimulates each child to increase his record; it produces group ambition; and it avoids keeping effort too long on the strain by monthly promotion.

The fundamental standing position is the best posture exercise because it strengthens the muscles used in holding good posture, it stretches the muscles of the front of the chest and contracts the shoulder blade muscles, and it trains the muscle sense and the proper nerve centers so that correct posture will be taken reflexly. It is difficult to secure good posture. Hanging from a pair of rings or a horizontal bar so that the toes just touch the floor is the best corrective exercise if care is taken to keep the head up. "Posture is a state of mind," says Dr. Joseph E. Raycroft.

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* Bancroft, School Efficiency in Relation to the Posture of Pupils. Address at the International Congress of School Hygiene, Buffalo, N. Y. (August, 1913).

Elevation cues for normal posture are:

Head: Up! (chin in)
Chest: Up! (high)
Waist: Flat! (abdomen)
Weight: Forward!

Lift the head!
Lift the chest!
Stretch the ankles!
Stand tall!

A good single cue is "Push up with your head" or "Stand tall."

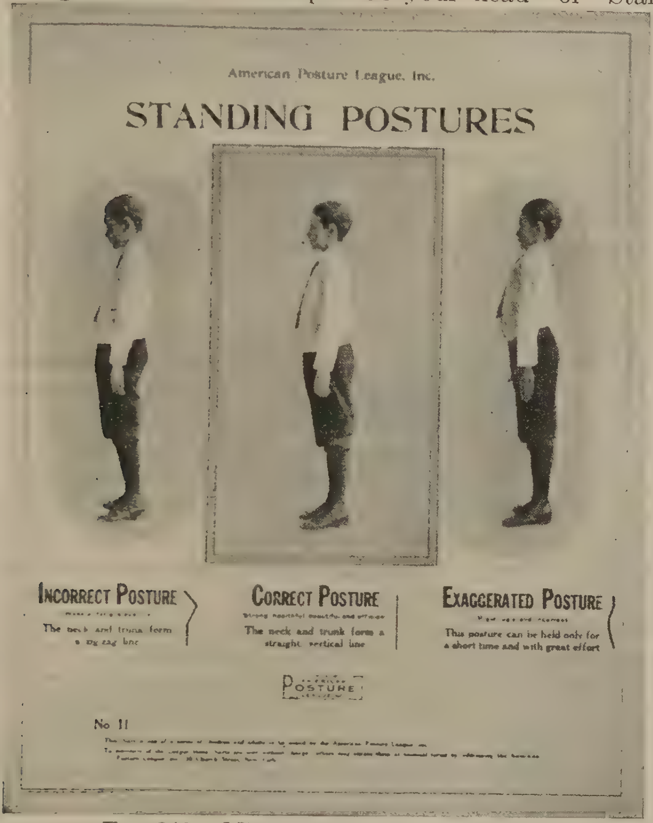
American Posture League, Inc.
STANDING POSTURES
INCORRECT POSTURE
The neck and trunk form a zig zag line
CORRECT POSTURE
The neck and trunk form a straight vertical line
EXAGGERATED POSTURE
This posture can be held only for a short time and with great effort
POSTURE
No 11

FIG. 249.—Miniature of wall chart No. 11.

Treatment.—Progressive improvement must be the criterion of efficient gymnastic treatment (Lovett).

The school should provide:
Special posture gymnastics.
Locker space for books.
Adjustable seats and desks.
Proper lighting of school rooms.
and advise the Correction of medical defects and poor nutrition.
Sufficient sleep.

See Spinal Deformities, p. 970.

SPINAL DEFORMITIES

Lateral curvature of the spine may consist of a single or total curve, double curvatures, or triple curvatures; and may involve any or all parts of the spine. The nomenclature of spinal curvature is based upon the position of the greatest point of spinal convexity, *i.e.*, "left dorsal curve" indicates that the convexity points to the left in the dorsal region. To accurately locate the curve it is desirable to mark the spinous processes, the crests of the ilia and the angles of the scapulæ with a flesh pencil. A so-called "thread screen" may be placed between the patient's back and the observer. This not only shows the spinal deviation, but the height of the shoulders and of the hips, and the distances between the patient's arms and sides. Rotation of the spine (which is an aggravated development of curvature) is best seen when the patient bends forward; rotation is then indicated by a bulging of the ribs on one side of the spine and a corresponding flattening of the ribs on the other side.

The four cardinal symptoms of Pott's disease or *tuberculosis of the spine* are deformity, pain, rigidity and weakness. Tuberculosis of the spine in a preponderating number of cases is indicated, in the earlier stages, by a slight projection backward of the affected vertebræ. A patient with Pott's disease guards himself carefully from the discomfort caused by active movements, thus protecting the diseased bodies of the vertebræ from jarring. When asked to pick up an object from the floor, for example, he may either squat on his heels or drop on his knees to prevent spinal movement, and when he rises he pulls himself up by a chair or other object so as to avoid the pain of muscular contraction in the back muscles. Stiffness is not confined to the affected vertebræ, but involves a larger portion of the spine. The presence of stiffness can best be ascertained by placing the patient in the prone position; the heels are then seized and pulled upward, or if he be an adolescent the examining hand is placed just above the knees which are then pulled upward, thus, in either case, determining the amount of extension to which the back muscles can be subjected. If the lumbar region is suspected, it is necessary to fix the thorax with the examiner's hand. Rigidity may further be demonstrated if the patient is placed on his hands and knees; when he is lifted from this position the trunk of his body remains rigid instead of relaxing over the hands which support it. If tuberculosis is present, the stiffness is marked and the maneuver produces pain. Different parts of the back respond differently to tubercular processes; disease of the cervical vertebræ produces wry neck, that of the lumbar region over-erectness or in many cases lordosis; pain does not occur at the site of the lesion, but, being due to pressure upon nerves at their exit from the spine, is referred to the region which they supply. It is seldom also that pressure elicits tenderness over the affected vertebræ, as it is the bodies, and not the spinous processes, which are involved.

Differentiation should be made between spondylitis, or Pott's disease, and sciatica, lumbago and pseudo-hypertrophic muscular paralysis. If there is psoas abscess, a diagnosis of hip disease must also be ruled out.[*]

FEET

The foot has two functions. It bears the weight of the body and raises and propels it in movement. Some normal feet curve out, some curve in, but most of them are straight.[†] There are two arches, the longitudinal, to which reference is usually made, and the transverse.

The longitudinal arch comprises the entire sole of the foot from the distal ends of the metatarsal bones to the os calcis. On the inner margin of the foot from before backward it is comprised of the first, second, and third metatarsals—the cuneiform bones, the scaphoid, the astragalus and the os calcis. This arch in the normal foot is permanent whether weight is borne on it or not. On the outer margin of the foot from before backward it is comprised of the fourth and fifth metatarsals, the cuboid, and the os calcis. When weight is borne here on the outer part of the arch it normally becomes flat.

The transverse arch is found at the junction of the anterior ends of the metatarsal bones with the phalanges. The second and third metatarsophalangeal joints are situated on a higher plane than the others except when bearing weight while standing; but in action the third metatarsophalangeal becomes very important, as it is the center of this part of the foot. Weakness of the transverse arch is almost never encountered among children.

The weight of the body is projected successively from the tibia to the astragalus, to the os calcis, to the powerful short plantar ligament and finally to the long plantar ligament. When the body is in motion the calf muscles pass the weight down from the center of the knee to the center of the ankle and forward to the ball of the foot at the second and third metatarsophalangeal joints and finally to the toes, the body in this manner being lifted over on to the other foot.

The longitudinal arch may be abnormally high or abnormally low.[†] There are many cases in which the abnormally high arch does not stand strain so well as the abnormally low arch. The height of the arch then is not a definite criterion of weak foot. The surest evidence of pronation or foot strain in mild cases is the position at which a plumb line dropped from the tuberosity of the tibia strikes the foot placed straight ahead. If it is farther toward the median line of the body than the cleft between the great and second toe, the longitudinal arch is pronated.[‡]

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[*] See Whitman, "Orthopedic Surgery;" Taylor, "Orthopedic Surgery;" Bradford and Lovett, "Orthopedic Surgery."

See Posture, p. 966.

[†] Ridlon, Lecture on Orthopedic Surgery to Line Officers. Unpublished.

[‡] Brown, Lloyd T., The Occurrence of Weak Feet and Foot Strain in School Children and Methods of Examination, fourth International Congress of School Hygiene.

In the *resting* foot there is a normal outward curve of the inner border extending from the first metatarsophalangeal joint to the os calcis. In the weight-bearing foot or passive attitude, this is obliterated because, "in *standing*, the astragalus through which the weight passes is rotated inward and downward on the os calcis until it is checked by the resistance of the ligaments and by the interlocking of the bones. The head of the astragalus thus becomes slightly prominent, and the inner border of the foot is depressed." This produces a small degree of abduction which increases the base of support desirably (Whitman).

In *walking*, on the other hand, abduction of the feet is very undesirable, because muscular action in this position is greatly curtailed. "The 'toeing out' of tradition is responsible for many cases of pronation or flat foot. Plantar flexion and adduction represent as contrasted with the weight-bearing or passive attitude of supporting weight, the attitude of activity in which the foot is supported and controlled by the muscles."*

The symptoms of flat or weak foot are a feeling† of weakness in the foot, awkwardness, *abduction*, and pronation. Another very important indication of weakness is stiffness to both active and passive efforts to twist and turn the foot inward at and below the ankle joint, so that when the attempt is made the muscles that turn the foot outward spring up, spasmodically contracted (Ridlon). Pain due to pronation is rarely present in children. Callouses frequently occur in adults and sometimes in adolescents and are an indication of weakness of the transverse arch.

The common causes of pronated feet are poor posture, improper position of the feet in walking and standing, incorrect shoes (either too narrow, too pointed, or too high heeled), insufficient development of the adductor muscles which should be stronger than the abductors, congenital malformation and paralysis, shortened tendo Achilles, weight carrying, malnutrition, anemia, fatigue. By far the most common cause of painful feet, perhaps 90 per cent., is infection elsewhere in the body with the resulting autointoxication.

Diagnosis.—If the patient, barefooted, is examined from the rear while he is walking, the normal heel will be in a direct line with the middle of the leg. If there is pronation the heel will be everted. When cases of pronation are examined from the front by the line test, the line falls inside the great toe and there is usually more or less sagging of the longitudinal arch. Abduction of the front of the foot is a constant factor. Walking in pronation is slouchy, and the leg is never completely extended.

A permanent imprint of the foot may be made by painting the sole with Freiberg's solution:

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* Whitman, "Orthopedics."

† Whitman, Armitage, Modern Treatment of the Flat Foot, Jour. A. M. A., lxxiv, No. 3 (Jan. 17, 1920), p. 151.

Tr. chloride 50 parts.
Alcohol (80 per cent.) 45 parts.
Glycerin 5 parts.

The foot is then planted on a piece of heavy paper. The impression is afterward intensified with a strong solution of tannic acid in alcohol. "Such impressions show the pressure-bearing surface of the sole."* The normal foot leaves no impress along the inner margin between the ball and heel and halfway toward the outer margin.

The shoe as a rule is worn off at the anterior inner border of the heel and the inner margin of the sole. The counter of the shoe is everted.

Range of Motion.—If the leg is fully extended at the knee, the patient should be able to flex the foot from 10 to 20° less than a right angle and to extend it from 40 to 50° beyond the right angle—the internal border of the foot can be raised twice as far from the floor as the external border. To test for a shortened tendo Achilles, have the patient stand with his back and heels against the wall, the feet parallel, about 6 inches apart. With the heels on the floor, have him raise the toes as high as possible. If the tendo Achilles is short there will be pain in the calf muscles.

Pain due to mechanical changes occurs chiefly at the internal lateral ligament and the calcaneo-scaphoid ligament and is often accompanied by lumbar backache. Other pain is usually toxemic.

Secondary Results.—Fatigue, bunions and corns, poor circulation causing hyperidrosis, cyanosis, and chilblains.

Treatment.—Insist upon good posture in standing and walking (p. 966); cross the feet while sitting. Correct the malnutrition by proper diet (p. 928, etc.). Insist upon long hours of sleep and avoid overwork either from study, weight carrying, or other cause. Remove all sources of autointoxication: adenoids, tonsils, defective teeth, otitis media, constipation, etc.

Exercises for the strengthening of the feet usually practised in the gymnasium are rising on the toes, and raising the toes while the heels remain on the floor.

The following exercises are much more helpful and can be used at home or in the corrective gymnasium:

1. With the feet adducted, rise on the toes and come down on the outer side of the soles. Repeat fifty times daily.

2. To develop the interossii, stand with the feet parallel on the edge of a chair, foot stool or curb stone, the toes projecting. Raise and lower the toes as far as possible (Ridlon).

3. To develop the arch; stand with the outer margin of the foot firmly braced against a wall. By vigorous action of the thigh muscles try to turn the foot against the wall. This raises and develops the arch of the foot (C. L. Lowman).

Passive Exercises.—Patient sitting with legs extended and toes flexed:

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* Taylor, Henry Ling, "Orthopedic Surgery."

(*a*) Invert soles of feet.
(*b*) with "*a*" extend ankle.
(*c*) with "*a*" flex ankle; repeat.

This may be performed as a passive exercise with resistance or without resistance.

Rooster Walk.—The patient should walk along a line with the inner lateral margin of the feet touching it, with the legs raised as the steps are taken and the foot in inverted position. As the foot comes down there should be an effort to dig the little toe into the ground as much as possible. Ten steps should be taken forward and 10 backward.

Ruffling Towel.—The patient should stand or sit in a chair. A large bath towel should be placed on the floor with one end under the right foot and the other end to the right of the body. With the lateral border of the right foot, the towel should be moved over, across the body, until it is on the other side. The left foot should then repeat the performance in the reverse manner.

Relay Race.—This is played with small objects, marbles, etc., which are picked up with the toes. It is conducted like a potato relay.

Game of Catch.—A rubber bath sponge or a tennis ball should be tossed with the feet in such position that the soles are inverted and in contact with each other. (Elsie Sameth.)

Shoes.—The modern heelless shoe for small children is suitable for normal feet.

For abnormal feet, shoes are modified by adding enough leather to the sole so that the line down the middle of the calf of the leg and through the ankle and the heel is straight, usually from one-eighth to one-quarter of an inch on the inner side of the heel, about half as much under the ball of the foot and more under the arch, so as to fill up the upward curve of the arch, rasped down to a thin edge following the flexure of the toes from the inner to the outer side of the shoe, thence backward along the outer side of the shoe.*

The American Posture League furnishes shoes for straight, for inflaring, and for outflaring feet.†

Shoes with a flexible shank increase the comfort of strong feet, but as a rule they decrease the comfort of weak feet until the muscles of the arch are developed by exercise.

A stiff shank is desirable for cross country or other rough walking, especially if the arch is weak. All shoes should be laced, straight on the inner side, broad across the ball, narrow and snug behind.‡ The heel should always be broad and except in cases of a shortened tendo Achilles, when the heel should be built up to meet the discrepancy, it should be both broad and low.

Commercial arch supporters frequently do more harm than good, both because they do not fit and also because the patient relies upon them for relief instead of developing the sagging arch by muscular exercise. A properly fitting shoe serves much better than the arch supporter unless the latter is made from a plaster cast of the foot by an orthopedic surgeon.

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* Ridlon, John, unpublished notes.

† Made by Burt, C. W.

‡ Taylor, H. L., "Orthopedic Surgery."

Feet that are lame and stiff must have rest. They will be helped by strapping with adhesive in a position of varus, starting below the external malleolus, passing under the arch to the inner margin, thence upward in front of the ankle and ending in a spiral around the leg. Two or three of these are necessary in order to hold the foot firmly. A pad of felt may be placed under the arch. Rigid feet should be under treatment of an orthopedic surgeon and may require operative interference.

SPEECH DISORDERS

Speech defects consist of faulty coördination of the nervous mechanism involved in speech and those muscles controlling expiration, vocal sound, and articulation, which are correlated with it. "Lungs, throat, vocal cords, mouth, nasal cavities, and the intricate system of muscles that control these parts, a sensory nervous system and a low brain sensory registration area, a higher brain interpretation area and intricate collaboration functions, a high motor-control area, a low motor-output area, which includes the nerves that go down to supply nervous control to the numerous external parts of the speech mechanism" are simultaneously brought into play.* It can readily be seen that such an elaborate connection requires the most exquisite, balanced, and harmonious functioning.

Defects of speech come under the following category:

Mechanical:
  Tongue tie
  Organic lisping } both due to malformations of the mouth.
  Nasality; due to the obstruction of sound waves in their passage through the nose.

Nervous and mechanical:
  Stuttering; due to spasmodic contractions of the breathing or articulatory apparatus, or both.

Nervous (organic):
  Spastic speech; due to over-innervation of the speech muscles.
  Scanning speech; due to Friedreich's ataxia.
  Indistinct, blurred speech; due to progressive bulbar paralysis.
  More or less complete loss of articulation; due to involvement of the basal ganglia.
  The aphasias; due to involvement of the various speech areas.

Nervous (functional):
  Negligent lisping; due to imitation.
  Hasty speech; characterized by precipitant utterance, due to imitation, fear of stuttering, rapid flow of ideas, or fear of interruption.

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* Swift, W. B., "Speech Defects in School Children and How to Treat Them."

Speech panic, or speech without inhibition; due to mental confusion with reference to speech, or to emotional excitement.

General Etiology.—E. L. Kenyon* states that there are at least one hundred and fifty thousand cases of stammering in the United States, and that 95 per cent. of them are initiated during the speech development period, about 87 per cent. in males.

Some of them are due to defects of hearing, some to adenoids, enlarged tonsils, missing teeth, high or defective palate, some to laryngeal difficulties. Others, on account of the emotional strain involved, owe their origin to an environment that is capable of producing a nervous twist—an unreasonable parent, a bullying big brother, any older person who laughs at or frightens the child, adjustments socially difficult for the shy child, insufficient sleep, fatigue from too much work or play, over-excitement from movies, coffee and insufficient food, mental defect, and inherited or acquired neuropathic tendencies.

Treatment.—It is often said that speech defects will be outgrown. This is so rarely the case, and results are so difficult to correct in later life, that great harm may be done by such advice. Stammering at best is very difficult to cure; the earliest indications of it should place the family of the patient on their guard, and great care should be at once instituted in regard to diet, sleep, exercise, happy firm even-tempered control, and freedom from all unnecessary irritation. On the other hand, stammerers should not be taken away from the surroundings in which they must eventually live. The patient must learn to live in and to live above the social difficulties of his environment, difficulties which have perhaps contributed largely to the embarrassment lying at the root of the condition.

Treatment is directed toward proper breathing, toward the correction of phonetic defects, and stuttering. Exercises in breathing accomplish double results: first, sustained control of the breath; second, concentration. As stuttering, and speech panic in large measure, and hasty speech in less measure, are due to mental floundering, to scattered concentration, the mind by embarrassment being confused or turned in upon its own consciousness, it becomes necessary to train the patient to a habit of objectifying his speech mechanism. *He must acquire the habit of turning his whole attention automatically away from himself to the thing he is doing.* He begins with a series of breathing exercises; these are followed by exercises in which the voice is held on a single musical note, or various notes. Presently a word is substituted for the pure sound; later sentences. As an aid to concentration, Swift advocates the use of such words or ideas in practising as involve strong visualization; for example: mother, star, lamb, etc.

The treatment of phonetic defects includes the following divisions: (1) Muscular development. (2) Ear sensitiveness. (3) Mental reproduction of sounds without vocal utterance. (4) Production of

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* The Problem of Stammering, and its Solution, The Laryngoscope (Sept., 1918).

muscular coördinations of speech, *i.e.*, the proper position of the external organs of speech for the articulation of vowels, consonants, or words not uttered, but imagined. This treatment, to be successful, should be continued till a correct and permanent habit is formed. In the space allotted to the subject here, it is possible only to refer to the main steps; for details see Dr. Kenyon's article and the bibliography at the close of this subject.

Swift advises that speech defects in school systems be under the superintendence of a physician who has been trained as a speech expert. He should have detailed knowledge of every case and should direct and outline the treatment. One teacher in each school, doing part-time grade work, should have special training by the superintendent, and conduct speech defect work with individual pupils, or in small groups, as the cases may require, either during school hours or perhaps preferably after school (in the latter case with special remuneration). Scientific records should be made, filed, and reported to the superintendent.

Children having phonetic defects may be regarded as cured when the new pronunciations have become easy, automatic and unconscious in ordinary conversation for a month. They should then return for observation, first at two-week intervals for three months, then at one-month intervals for a year. The stutterers require watching for two years

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See also articles by Hudson Wakner.

MENTAL HYGIENE

The hygiene of the nervous system involves the brain, medulla, cord, nerves, sensory organs and sympathetic nervous mechanism, the motor apparatus, the visceral organs: heart, lungs, kidneys, the endocrinous glands, etc. It involves development, integration and disintegration within the organism itself and adjustment to an ever changing environment. It involves reflex acts, those fundamental instincts with which the organism is either equipped at birth, or which develop later; sensation, perception, habits, association, memories, imagination and such activities of nervous matter as produce the higher intellectual processes; conception, judgment and reasoning. It involves the internal emotional forces that furnish the inspiration and trends of behavior and the tendency of instincts to strive persistently for the accomplishment of their natural ends. This latter tendency involves attention to a high degree and, if combined with efficient habits results in volition which controls and subdues emotion, produces stability and unity and power to rise from one level to another. All of these factors have a biological foundation and are developed as the result of experience, either inherited or acquired. It is the purpose of this article in the limited space allowed to study cursorily and very simply both normal and abnormal psychology and behavior from this point of view and to indicate, in a more or less general way, methods that have proven to be practical in securing hygienic mental habits or education.

Reflex Acts.—Life, from its most simple to its most complex forms, is dependent upon the power of the organism to breathe, to eat, to circulate oxygen and food and to eliminate waste products. The very necessities of development require a certain amount of fundamental equipment and the ability to respond automatically, without conscious thought, in certain definite, hard and fast ways to certain corresponding definite stimuli.

In the early forms of life, before the development of the central nervous system, these stimuli are received by some sort of a sensory apparatus, the impression is conveyed by some kind of a path of conduction and a synapse or synapses exist somewhere which receive the impression, connect it with and send it out from the motor centers to the motor organs. These simple reflexes are called simple or "unconditioned" reflexes.

Before the experiments of Pavlov and his school it was supposed that the response to every primary reflex was the result of some specific stimulus and that this was invariable. If for instance, secretion from a secretory organ such as the salivary gland was desired, food in some form was of necessity the specific stimulus that produced the response. Pavlov's experiments show that if another sensory stimulus is associated with the act of feeding at the same time or with sufficient intensity, or even if the stimulus is indifferent but repeated frequently with the primary stimulus, there occurs what is called a "conditioned reflex" which in time is capable of being invoked independently of its original associate; in short, "A conditioned reflex is a reflex produced by any indifferent stimulus associated with a biologically adequate stimulus so that the associated indifferent stimulus produces precisely the same physiological effect."*

For example: if a dog is given a piece of meat saliva flows. This is an unconditioned, invariable reflex. If, each time the meat is given, a bell is rung, the sound alone eventually invokes the same flow of saliva. This, a physical example of the "conditioned reflex," is the result of association and is therefore performed by the cortex. Such instances are not confined to physical experiences but occur in every avenue of activity in the life of higher animals, especially in man. The possibility of substituting associations that are naturally remote for those that are direct make the ramifications of the "conditioned reflex" enormous. Conditioned reflexes start probably before the first year of life and eventually affect habits, association systems, mental attitudes, emotions and action. They correspond in some degree probably to the "acquired afferent inlet" of McDougall (Social Psychology).

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* Burnham, W. H., The Significance of the Conditioned Reflex in Mental Hygiene, Mental Hygiene, v, No. 4 (Oct., 1921), p. 673.

Shock, resulting from sudden noise or the appearance of terrifying objects, produces permanent harmful associations which continue to create fear with the re-occurence of the noise or the re-appearance of the same or similar objects long after the child's mind is capable of understanding the innocent character of the cause. If conditioned reflexes controlled the situations of life without modification, behavioristic problems would be insurmountable. Fortunately the law of protagonist and antagonist, of action and inhibition works throughout nature. The power of inhibition in this relation also has been made clear by Pavlov's School. Not only have they discovered the influence of secondary stimuli, the conditioned reflex upon secretion, *i.e.*, the possibility of substituting a sound et cetera instead of food as a stimulus but they have also found after thoroughly establishing the secondary factor, that this in turn may be influenced by a third factor which deters or inhibits the second, so that the first may resume its function. For example: when an experimental dog was struck immediately after or at the same time a flow of saliva had been instigated by the specific sound which had already produced a conditioned reflex of some stability, the new stimulus inhibited the specific stimulus so that the saliva did not flow. Such inhibitions occur with every conditioned reflex and serve to give the organism unity of action and stability. They begin to appear before the end of the second year. This process is multiplied: "Each extra stimulus in turn inhibits the conditioned activity of the brain, superimposing itself on the process it encounters in every part of the same. If it meets with excitation, it inhibits the excitatory process; if it meets with inhibition, it inhibits the inhibition." Thus the child starts his career free and unconditioned. By the end of the first year, the relative intensity of associating factors produces conditioning of the organism's reactions and by the end of the second year social adaptation requires the inhibition of these associations. The inhibitions of life produce two effects. Under normal conditions they produce habits of self control. On the other hand, many of the more inconsequential usages of polite society produce habits of inhibition which cripple and stultify some of man's noblest possibilities for capacious development and service.

Instincts.—As the conditions of organized life become more complex, both survival and progress require the united coöperative effort of a number of reflexes for the accomplishment of functions that are essential to existence. Instinct is, however, something more than a compounding of reflexes; each instinctive experience having its origin in a* "sense impression or combination of sense impressions, psychic in nature, which excite some perfectly definite behavior, some movement or train of movements which is the same in all individuals of the species and on all similar occasions; in general, the behavior so occasioned being of a kind either to promote the welfare of the individual animal or of the community to which he belongs, or to secure the perpetuation of the species." Specifically, instincts, as a rule, involve adjustments to heat, cold, the procuring of food and the development and protection of the person or family. These functions are so important and they are so intimately bound by the desires or satisfactions and the annoyances or repulsions of life that they arouse emotion almost as soon as they are invoked, thus becoming paramount determiners of animal behavior. Instinctive behavior occurs either as the result of attraction or repulsion. In either case, it is the tendency of any instinct aroused to fulfill itself and thus requires volition. We have therefore in instinct the germ of mental, emotional and self-directive life. This is well shown in the experience of a hen and her brood when a hawk appears in the sky. The hawk is an ancestral foe from whom, whether experienced or inexperienced, gentler birds have an innate, unlearned tendency to protect their young, to flee and find refuge. The instinct is aroused by information conveyed by the senses to the mind, producing instantaneous emotion in the form of fear, which results at once in repulsive action, manifested in weaker animals by flight and concealment; action which dominates the subject until she accomplishes her purpose. The following is Kilpatrick's list of instincts:

I. Individualistic, or Self-preservative Instincts:
    Feeding
    Fearing
    Fighting
II. Parental Instincts:
    Sex and courtship instincts
    Singing
    Self-exhibition
    Fighting for mates
    Nest building
III. Group or Social Instincts:
    To arrange themselves in groups
    To coöperate for the common good in attack and defense
    Seeking companionship
    Desiring the approval of the group which one joins
    Pride
    Ambition
    Rivalry
    Jealousy

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* McDougall, "Social Psychology."

  - Embarrassment
  - Shame

IV. Adaptive Instincts:
  - Tendency to spontaneous movement
  - Tendency for nervous energy to take the same course that has just been taken
  - Tendency to imitation
  - Tendency to play
  - Tendency to curiosity

V. Regulative Instincts:
  - The moral tendency to conform to law
  - The religious tendency to regard a higher power

VI. Resultant and Miscellaneous Instincts and Feelings:
  - The tendency to collect objects of various kinds and enjoy their ownership
  - The tendency to construct or destroy, and the pleasure of being a power or a cause
  - The tendency to express mental states to others of the species and to take pleasure in such expression
  - The tendency to adornment and the making of beautiful things, and the aesthetic pleasure of contemplating such objects.

The following is a brief résumé of Thorndike's* analysis of the inherited tendencies of man:

Large Body Movements.—Placing the body in position (sitting); moving from one position to another (running).

Movements of Individual Parts of the Body.—Kicking, crying, manipulation, and investigation, appropriation or rejection of objects that are grasped.

These movements in various combinations are employed for the purpose of securing certain materials or situations that seem essential to life or comfort, and include food getting, shelter getting, defense, and sex behavior (the latter after adolescence). There are also play responses; such as following the crowd, rivalry, imitation; and certain general tendencies, such as the tendency to change the original responses and to develop skill not present in original nature; the tendency to pick a situation to pieces and to respond to certain aspects of it; the tendency to get sensations and to be satisfied with mental control of sensations (frequently called curiosity, constructiveness and destructiveness, but probably not thus distinguished in original nature); the tendency to be satisfied when an instinctive response is successful, and annoyed when it is not, or to be satisfied by certain sensations or conditions, and annoyed by others. "Things that satisfy or annoy are of overwhelming importance in establishing habits." Thorndike names the following as independent sources of annoyance: "pain; bitter tastes; the sight, touch and smell of entrails, excrement, and putrid flesh, touching slimy things; depression, as in fear, grief, the absence of human beings, their disapproving behavior, and very intense stimuli of all sorts."

"The chief independent satisfiers are sweet, meaty, fruity and nutty tastes; glitter, color and motion in objects seen; being rocked, swung and carried (in childhood); rhythm in percepts and movements;

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* Thorndike, Edward L., Educational Psychology, i.

elation; the presence of human beings, their manifestations of satisfaction, and their instructive, approving behavior". . . Other things being equal, to have sensations, to initiate movements, and to make things happen are satisfying . . . Tendencies to general mental activity and general physical activity, when given exercise, satisfy; and when denied exercise, annoy. The conduction units involved in many situations—response series—also in due time crave exercise, *i.e.*, become ready to act, so that imaging or thinking may as truly become a want as food when hungry, or capture after a chase.

"On the whole, it seems best to assume, subject to further knowledge . . . that any state of affairs is originally satisfying which lets a conduction unit that is ready to conduct do so, and that any state of affairs is originally annoying which forces an unready conduction unit to conduct or restrains from conducting one that is in readiness."*

Reference is made later to a study by Thomas of the desires of Polish immigrants. These he classifies as desire for new experience, for mastery, for recognition, and for safety (p. 1003). It would seem as if these four points very nearly cover the "satisfiers" enumerated and described by Thorndike, and that it is important to recognize their existence as well as those of the annoying type, as factors to be dealt with intelligently.

Each instinct has its own time for appearing, and can be atrophied by disuse, or developed by use. The adaptive instincts; imitation, curiosity, constructiveness, acquisitiveness, and play, and the regulative instincts, moral and religious behavior and some aspects of fear, have such an important place in the development of the child that their proper cultivation is very essential. On the other hand, instincts of shyness, unsociability, secretiveness, jealousy and other aspects of fear are sometimes the source of obsessions and serious mental disease. If they are recognized at the proper time, they can almost always be successfully eliminated.

The following is a statement of the more noticeable instinctive physical and mental characteristics that appear from infancy to puberty:

Infancy to Three Years.—This is the most rapid period of growth; body movements are large and fundamental, and made without sustained attention. They are due to the instinct of multiform physical activity. See Thorndike's analysis above. Other instincts which appear at this time are feeding, fearing which begins early, anger with and without fighting, jealousy, embarrassment, tendency to habit formation, to imitate, to play, to curiosity, to express mental states to others of the species and to take pleasure in such expression. The ability of the senses to perform their particular functions is developing rapidly and speech is being acquired. The child imitates the exact movements and sounds of adults and plays alone or with adults. The importance of this period cannot be over-estimated for it is at this time that the emotional trends are established. The future of the child depends largely upon the ability of parents to organize the child's instincts and habits at the outset so that there shall be regularity of behavior and a constant uniform relation between cause and effect. As has been said, conditioned reflexes originate in the early years of life. They originate for the most part in connection with the mother's appearance and attitudes. Fear, anger, love in their various manifestations, act as stimuli and produce tendencies not only directly but also by means of their associations. Imagination appears about the third year.

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* Quoted by Hartshorne, "Childhood and Character."

Four to Six Years.—There is steady progress in physical growth, but poor coördination. This is a period of free motor activity and dramatization, the latter being based upon the imitation of adults, which the child adapts to his own play concepts. Children play with other children at this time, and imitate them freely, but they are selfish and assertive and, for the most part, coöperate poorly with each other. Imagination is vivid and interest (curiosity) is at a high pitch, as indicated by the questions which at this period are interminable. This is also the time to stress regular biological habits of sleeping, eating, and body functioning.

Seven to Nine Years.—The quantity of motor activity is lessened; skill and feats of strength, however, enter into the child's motive. Individualism, competition, emulation, and the instinct of self-assertion are the prevalent forces. Physically, heart development falls behind the growth of the body as a whole, while the large blood vessels develop more rapidly.* It is, in general, a period of slow physical development, amounting, not infrequently, to physical retrogression, with weakness of the heart (p. 946).

The age of nine years and the *early part of the tenth year* is often a very difficult period. There is a transition involving the mind and the body which makes radical adjustments necessary. Body changes are represented by a difference in reactions to immunity, and personality changes; by substitution of multiform mental activity for multiform physical activity (p. 922). It is just at this period that children as a whole seem to regress. It is because they are leaving childhood behind and are not yet adjusted to the greater responsibilities that are just ahead.

Ten to Twelve Years.—This is the height of physical energy; more games are played now than at any other time. There is far greater coördination of sensory and motor activities, so that *skill* stands out obviously as the predominant motive. Children of this age are acquisitive. This is in correspondence with the general tendency toward individualism, and is manifested by collections of stamps, buttons, etc. The tendency to acquire objects becomes universal at this age, and lasts through adult life. Even though group plays (team games, etc.) are common at this period, the group spirit is submerged by the individual's impulse to glorify himself in the game. It is an important point that children at this time are less interested in adults, and less influenced by them, than at any other period of life.

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* See Gundobin, "Besonderheiten des Kindesalters," p. 124.

Thirteen to Fifteen Years.—These years are characterized by the greatest increase in muscular development and control of the accessory muscles. The size of the heart increases rapidly in relation to the blood vessels, and the blood pressure, lung capacity, and grip are also increased. Association fibers of the brain develop extensively; there is rapid and often unstable development of the emotions; love, pity, fear, anger, jealousy, emulation, ambition have a new awakening, corresponding with the development of puberty. On the other hand, there is also a growth of such characteristics as laziness, awkwardness, self-consciousness, tendency to reverie, dreams of greatness, mannerisms, self assertiveness, and desire to show off. The herd instinct* here appears, it is the period of hero worship, and it is also the age at which the group or social instincts and the regulative instincts appear. A spirit of altruism is prominent, there is greater susceptibility to both religious and criminal tendencies, and of choice. It is fortunate that the heroes are usually adult instead of youthful companions.

Sensations.—There are evidences very soon after the birth of an infant that it becomes conscious of light. At least, if a bright light comes within its range of vision, there is a diffuse muscular reaction; that is, the arms and legs, in fact the whole body, responds by large purposeless movements. If the light is too strong, the child sometimes cries. By the same signs it is apparent also that loud sounds are recognized very early. Light, sound, heat, softness, size, pain, etc., are qualities which compel adjustment of the body. They arise either as a result of the internal spontaneous physical activity of the body, such as movements of bones and joints, sensations from body functions, etc., or from external objects. When a specific quality consciously stimulates the sensory organ designed to respond to it, there is an adjustment of that organ, and the result is a sensation emanating from and related to the object from which it arises. The object, however, is not recognized as such, consciousness at this very early stage dealing only with qualities or with the vaguest and most rudimentary percepts. Sensation, therefore, is the earliest intelligent reaction, and the basis from which all mental progress develops. Two facts are of paramount importance in connection with sensation: first, the necessity of normal sense organs and a normal nervous system; second, the necessity of sensory training for the purpose of producing habits of careful observation and accuracy, together with a growing richness of mental experience (articles on Visual and Auditory Defects).

Perception.—Pure sensation which occurs only with the individual's first experiences is unattached and therefore meaningless. In order to make it of significance the muscular apparatus is compelled to make such an adjustment that the *object* from which it emanates is experienced. Every object is composed of a permanent group of specific qualities, which give it its individuality and make it different from every other object. Each time an adjustment is made the constancy of the relation of the qualities that make the object becomes more evident. A preception, therefore, may be defined as the consciousness of an object or thing produced by the stimulation of sense organs, to which we always react in the same way. The extent and accuracy of an individual's perceptive background depends upon his native ability to observe, his opportunities for observation; *i.e.*, travel, experience, etc., and his training in observation. Some teachers use crude, unassociated sensory material in developing a sense of color; for instance, they teach children to match colors without any significant objective basis. If pure sensation is meaningless, it can be readily seen that in developing sensory discrimination the learning process will be greatly facilitated if color, for example, be taught not arbitrarily, but in its rightful connection with objects or percepts. It is clearly an advantage to teach green in association with grass and trees, blue with the sky, yellow with dandelions. When the essential relations of qualities and objects are established there is a foundation for further steps in consciousness.

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* Trotter, W., "Instincts of the Herd in Peace and War."

Habit.—In discussing sensation, mention was made of the fact that when the eye or any other sensory apparatus is stimulated, large spontaneous muscular movements of the entire body result. Out of this diffuse reaction some particular movement may occur that accomplishes a purpose and brings satisfaction. Efficient action in some definite direction makes a deeper impression upon plastic nervous tissue than diffuse action, therefore when the same stimulus is repeated the response is likely to follow the efficient pathway. This is the beginning of habit. Habit, therefore, from the neurologic point of view has been defined "As a path of preferred conduction between stimulus and response set up by and due to the life experience of the organism."

Habit, with instinct, is the basis of behavior. Consider, for example, the habit of punctuality, which begins with the child's second feeding experience. Irregular feeding habits engender harmful emotional and unhealthful biological reactions; the beginning of disordered emotion, uneasiness and crying, disturbed digestion, poor appetite, malnutrition, diminished immunity, and irregularities of "sleep and waking, and resting and activity." Regular feeding habits produce a feeling of coeneasthesis and healthful biological reactions, and form the background not only of the individual's capacity for an appreciation of time values, but for a consideration of the corresponding time values of his fellows. Social and anti-social relations are closely correlated with punctuality. Any single habit of punctuality rapidly organizes into systems of related habits, and then into hierarchies in which the universe itself is in correspondence. The child who is out of harmony with such firmly set foundations is seriously handicapped from the start.

Correct habits simplify movements, increase speed and accuracy, diminish fatigue, permit the performance of several activities at the same time on account of their automatic nature, and leave the mind free to do more difficult things. When any new habit is begun, progress is very rapid at the outset. After a time, however, unless there is a sufficient incentive, perhaps because interest is lost, perhaps on account of some defect in the automatism, progress slows or stops. At this juncture it is important to analyze the separate factors which compose the habit, in order to discover which one is causing the difficulty. In number work the trouble may lie in a lack of familiarity with the multiplication table or number combinations. In physical education or in the play of little children* progress may cease until awkward movements are substituted by simpler, freer types. If it becomes necessary to make such new adjustments, there should be a thought crisis or definite consideration of the situation to bring about an understanding of the difficulty, followed again by more intelligent practice when, once more, the new method becomes automatic, and progress proceeds. "The higher the incentive to the formation of a habit, and the more uniformly this incentive is maintained, the more rapidly and the more uniformly will the habit be formed." Watson† records some very illuminating experiments made along this line.

Allusion can only be made here to James' rules for the establishment of habit. They will be found in "The Principles of Psychology," (1890), i, Chap. iv. In short they are as follows: The necessity "of launching the undertaking with as strong an initiative as possible, of allowing no lapses, of taking advantage of every concrete opportunity to act in the right direction, and to keep the faculty of effort alive by a little gratuitous exercise every day." In dealing with little children, emotional elements such as happiness, comfort and freedom are prime essentials in establishing good habits, because through them interest and coöperation can be secured. Colvin emphasizes the value of eliciting the child's power of imitation by using stories of soldiers to secure better habits of posture. Miss Bancroft's methods (article on Posture) with older children obtain the same habits, and even drill can be made attractive by the use of charts which demonstrate to the child his own progress.

Volitional life is also largely the result of habit. If habits of control form the background of moral behavior, if the child is educated from the beginning, he establishes habits that lead to stability and unity; habits of self control, independence, initiative, "habits for team work, an ability to mix, to respond to others, and to make them respond, an ability to understand and to be understood, and to enjoy and to be enjoyed, to meet the unusual or perhaps the undesirable, such as sickness, and varying amenability to discipline and to guidance, and capacities to assume responsibilities and duties." Thus he is fitted for a very high degree of personal satisfaction and of moral and social usefulness.

Education is the process of development that occurs in an organism. It is based upon the instincts or spontaneous tendencies of the individual's original equipment, upon factors in the environment, with and without "conditioning" and is controlled and integrated by the establishment of habit.

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* See illustration, Colvin, "Learning Process."

† "Suggestions of Modern Science Concerning Education," p. 84, etc.

Psychologists are endeavoring to find those methods in the learning process which will conserve mental and physical energy, develop latent and overt ability, and establish a rational hygiene of instruction. The learning process has certain fundamental experiences that are common to all learning. An understanding of them, therefore, is essential in considering the facts that lie behind the hygiene of instruction. The effect of instinct, environment, and habit as educational determiners may be seen any day in the spontaneous play of children. A typical illustration of the learning process demonstrated through play was seen recently by the author in the day coach of a western bound train. It is related exactly as it occurred:

A young mother who had had a nurse's training was busy knitting and chatting with a fellow traveler.	A sensible mother; freedom.
Her fat, happy little son, 2½ years of age,	A normal nervous system and a normal body.
slipped down from beside her to seats across the aisle arranged *vis a vis*.	This is a response to confinement, and involves cerebral connections expressed in mental control and curiosity, gross bodily control, minor bodily movements expressed in play. The child also shows initiative.
The open space between these seats presented an interesting situation to the child. He climbed upon one of them with some difficulty,	Visual exploration, concentration, choice of a problem, and a vague desire to accomplish a purpose, which becomes better defined as activity progresses. Mental and bodily control. Procedure is based partially upon the memory of success in similar previous experiences. Judgment of probable success or failure is based upon sensory and emotional memory. Measurements of space are determined by eyes, muscle sense and previous motor experience.
and then cautiously, in a creeping position, began the conquest of his task.	Fear is overcome by the tendency to have pleasure in being a power, and by interest and courage based on previous success.
Facing the opposite seat, he reached over, first placing one hand on it, and then the other, following this by the legs in rapid succession. When he was safely across	Trial. Success.
he started to go back, repeating the process until he was possessor of a well fixed and well coördinated series of habits of motor control.	Motor habits established. Development of positive self feeling, or assurance.
The next procedure was to jump across the space in the upright position; first, one foot at a time. Later he bridged the gap in a standing broad jump.	Awkward and useless motor coördinations are discarded, and better habits of motor control established by elimination of early biological muscular adjustments. Action is more

	precise, rapid, automatic and sure. Result: Conservation of energy and increased ability.
This last performance was accompanied by all the manifestations of mastering behavior: Shouting, laughing, and wild swinging of arms.	There is the freedom of a perfected action, "The inspiration of power felt," accompanied by manifestations of exuberant joy.
This attracted the attention of another boy in the car who was, perhaps, a year older, long limbed, and agile.	The appearance of a second child, No. 2, who had reached the gregarious stage, while the little fellow 2½ years of age still preferred to play alone.
Disdaining the attainments of the younger one, No. 2 at once began to scale the heights of the adjoining seat backs, and succeeded easily in vaulting over them.	No. 2 undertakes successfully a much more difficult problem.
The fat little boy (No. 1) at once tried to follow him.	Observation of another's performance. Recently gained assurance transferred to new situation. Ambition, rivalry (social instincts), imitation (adaptive instinct).
but failed repeatedly.	Adaptive difficulty. Conflict, trial, and error (failure).
Finally he gave it up, and withdrew altogether.	Shame. Negative self-feeling and subjection. Disappearance of joy, and withdrawal.
Sitting quietly, without special occupation, by his mother.	Rest; time for association processes to organize.
Some stations farther on, the older boy left the train with his father.	Removal of irritant. If this boy had been a frequent companion, he might have become a "conditioned reflex," which would have seriously hampered the development of No. 1.
Then the little fellow tried the seat backs again, and this time, with considerable effort at first, he dragged his body over them.	Repeats efforts in which he failed previously. Adaptation secured. Trial —*Success!* Reëstablishment of positive self-feeling, or elation, and conflict reduced.
Back and forth he went, each time more easily, until he had mastered the situation.	Repetition. Habit formation. Results in better mental and motor associations, and self control.

The above illustration should serve to emphasize certain characteristics of the learning process which are essentially hygienic. Free self activity combines with interest, producing initiative and concentration. Interest overcomes fear, and quickens sensory and motor adjustments. This results in conservation of energy by the abandonment of superfluous coördinations, and a permanent and a higher integration. And further; it represents a factor in education that is stressed by many of the best teachers to-day. Both John Dewey and Mrs. Marietta L. Johnson of Fairhope, Alabama, emphasize the importance of freedom. Children, they believe, should have the experience of choosing their occupations and of carrying them through to an end. Dr. Dewey has epitomized the significance of such episodes as the above, which represent the fundamental factors of efficiency in education, in the title of his book: "Learning by Doing."

Association.—If a beaten path appears in the forest, the unaccustomed traveler chooses it. Everything else being equal, it is both the way of least resistance and the path which leads somewhere; that has a connection already established. All experiences must have occurred before to have formed associations. Thus it is that association is the result of habit, habit being the pioneer that deepens the trail in nervous tissue over which associations proceed and by which permanent connections become possible.

Nervous tissue has a tendency to bind experiences which have the following relations:

1. Those which are related in time and space.
2. Those which are sufficiently similar or different to produce interest and hold attention.
3. Those which are particularly vivid.
4. Those which have been frequently repeated.
5. Those which have been recently repeated.
6. Those in especial harmony with the personality of the individual or with his mood at the time they occur.

Associations with close *time* and space relations, and with relations of *similarity or difference* are called primary associations because they are stronger than the others. We say "This reminds me of that" because it may have some point of similarity or difference, or because it occurred at the same time, or because it may have occurred in the same situation. Vividness depends upon the force of the initial blow, and this depends not only upon the imaginative skill of the producer of the impression, but also upon the imaginative impressionability of the receiver. Emotional experiences are apt to be more vivid than intellectual, because they are so closely related to the desires of organic life. Attention is definitely focused upon connections of this type, therefore they do not easily fade. Intellectual associations are coupled with vividness when the subject matter is of great moment, or presented with brilliancy and power, and this depends both upon the clearness of the original perceptions that gave rise to the ideas presented, and to the reactions which they produced.

In order that material may become thoroughly incorporated in the mind, it should be associated so far as possible with a background already established; not in isolation. It is necessary to fix some of our fundamental knowledge, however, in quite a different way; that is, by repetition or drill, as in the multiplication table. At best, this is a laborious process, because it has so few interesting connections. To secure satisfactory learning of this type outside factors must be introduced. Emulation with others in the same class, or with the child's own previous record, which can be watched if his daily progress is charted, serves in some degree as compensation for interest.

Directness of association is a very important factor in connection with school hygiene. Little children and stupid children are benefited by a proper use of devices such as maps, the abacus, etc., because they help in fixation. If they are overemphasized, however, nervous children are sometimes harmed by them because they can produce disorderly or unimaginative mental activity. Instead of serving only as the scaffolding, for which they were intended, they can be used in such a prominent way that they become permanent features like a "half-way house" at which the mind is forced to stop on its way to the goal. For instance, children who have used the abacus in learning number combinations sometimes continue to bring it before the mind in every number operation long after their number habits are sufficiently formed so that they could do without it. Other teachers overdo the map device. The beauty, power, and economic value of Niagara Falls may dwindle into insignificance before a spot on the map. The ingenuousness of Huckleberry Finn, for the purpose of scientific illustration, may be a little overdrawn, but he is an admirable illustration of the point at issue.*

"There was one thing that kept bothering me, and by and by I says: 'Tom, didn't we start East?'

'Yes.'

'How fast have we been going?'

'Well, you heard what the professor said when he was raging round: sometimes he said we was making fifty miles an hour, sometimes ninety, sometimes a hundred; said that with a gale to help he could make three hundred any time, and said if he wanted a gale, and wanted it blowing in the right direction, he only had to go up higher or lower to find it.'

'Well, then, it's just as I reckoned. The professor lied.'

'Why?'

'Because, if we was going so fast, we ought to be past Illinois, oughtn't we?'

'Certainly.'

'Well, we ain't.'

'What's the reason we ain't?'

'I know by the color. We're right over Illinois yet. And you can see for yourself that Indiana ain't in sight.'

'I wonder what's the matter with you, Huck. You know by the color?'

'Yes, of course, I do.'

'What's the color got to do with it?'

'It's got everything to do with it. Illinois is green, Indiana is pink. You show me any pink down here, if you can. No, sir, it's green.'

'Indiana *pink?* Why, what a lie.'

'It ain't no lie. I've seen it on the map, and it's pink.'

You never see a person so aggravated and disgusted. He says:

'Well, if I was such a numbskull as you, Huck Finn, I would jump over. Seen it on the map! Huck Finn, did you reckon the States was the same color out-of-doors as they are on the map?'

'Tom Sawyer, what's a map for? Ain't it to learn you facts?'"

Irrevelant or meaningless association by confusing the issue often produces the ground for mental conflict and worry.

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* Mark Twain, "Tom Sawyer Abroad."

A number of the major psychoses characterized by flights and confusions are the result of disturbances of association. In a predisposed child, serious arrests of mental development or the beginning of dissociation may occur, because the child has been placed in the hands of an unsympathetic, critical teacher. Retarded children and children who draw within themselves require an atmosphere in the schoolroom which will foster the development of rich, direct, well related associations. This can be brought about by both interest and happiness. "Tasks, therefore, should be simple and definite; instructions clear and concrete; decisions and actions straightforward and whole hearted. Thus habits of orderly association are produced."*

Memory is the natural outcome of association, but in order to make ideas permanent in the mind, or in order to grasp them, there must be time for association processes to organize and consolidate. Rest, therefore, in some form or other, is absolutely essential as a final step in association. The following experiment by Mueller and Pilzecker illustrates this point:

"After learning a series of nonsense syllables by the method of paired associates, *i.e.*, 'baby—infant,' etc., they gave the observer a task requiring concentration of attention a few seconds after the learning of the original series was completed. In another series the task requiring attention was given six minutes after the original series was learned. A test was made of what was learned one and a half hours afterward, and it was found that of the first series only 28 per cent. was remembered; of the second series 49 per cent." "This is remarkable evidence," adds W. H. Burnham,† "that a process of consolidation does occur. *Haste in learning* may defeat its own end. It is not a matter of indifference to health whether five or six hours a day for the long period of school life be spent in hurry, nervousness, or confusion, or in developing habits of concentrated attention and orderly association. The former conditions account for instability and nervous irritability among Americans, resulting in nervous breakdowns, thus making re-education necessary." Kraepelin's paradoxical statements are significant:

"Inattention in children is their salvation, and uninteresting teachers a hygienic necessity." And further: "Uninteresting teachers are also a pedagogical necessity because they alone give children the periods of idleness necessary for the organization of permanent memories of what may happen to be learned."

Imagination.—In the case of memory, if an object has made sufficient impression upon the mind, it can be recalled and, in a sense, re-experienced; but to fall within the realm of imagination it is essential that the object be recognized as having no real present relation to the senses. Imagination, therefore, may be defined as the mental process by which we reproduce sensory objects and ideas in ways not previously experienced, interpreting them to ourselves as unreal. Further, except in a few highly imaginative normal children, whose images are sometimes so fantastic as to partake of the nature of illusions and hallucinations, normal images are of such a nature that they will fit in as a genuine possibility with the other objects and experiences of the world.

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* Burnham, W. H., Mental Health for Normal Children, Mental Hygiene, ii, No. 1 (Jan., 1918).

† Mental Hygiene in the School, Fourth International Congress of School Hygiene, iii.

There are two kinds of imaginative thinking: Reproductive, which rightly belongs to memory and looks backward, and productive imagination, by which the mind brings together previously experienced material in new combinations and relates itself either to the present or to the future. The mind is thus enabled to handle the objects of the external world and ideas with great flexibility, becoming creative and in the truest sense constructive.

To be of value, it entails accuracy of sensation and perception, the power to recall, to form new ideas, and to reason about them. There are two main classes of imagery: *object types* and *word or symbol types.* Under the former occur all the concrete images that have been developed through sensory experience, mainly through the eye, the ear, and the kinesthetic sense, *i.e.*, the sense of touch and muscle-sense. The kinesthetic sense is sometimes used alone for the purpose of investigating the feeling of objects. Usually, however, it contributes to experience indirectly by reinforcing impressions gained through the other senses by movements that have been made in handling the objects that gave rise to the images. If the symbols used in imagination have been conveyed to the mind by the eye, they come under the category of visual imagery; if by the ear, auditory imagery; if recognized as the movement of the articulatory apparatus, especially the throat, they are called verbal-motor, a form of kinesthetic imagery. Gestures and dramatic symbolization also belong under the latter heading. Illustrations of visual imagery, are occasionally encountered in modern billboard advertising. During the recent war several signs of similar character appeared, in which it was necessary to supply considerable proportions of the human figure by the imagination. Many will recall a poster consisting only of a soldier's head, collar, hand and the rim of the cuff and wrist-band. The advertisers depended upon the past experiences and the imagination of the observer to supply the chest, shoulders and arms. Beethoven is a colossal representative of auditory imagery, all of his symphonies having been composed after he became deaf. There are very few exhibits so significantly pathetic as the collection of ear trumpets in a show case in his house in Bonn. From a sensory point of view, Helen Kellar owes the richness of her life entirely to kinesthetic imagery as the sense of touch has been her only direct medium of approach to the world.

Word or Symbol Types.—These have to do with the symbols or representatives of objects (see paragraph on the concept), such as words or heiroglyphics in writing, notes in music, etc. The child is not very old before he begins to use symbols or words independently and imaginatively without recalling the objects for which they stand. Were this not true, mental work would be so hampered by a multiplicity of detail that judgment and reasoning under ordinary conditions would be impossible (p. 998). Nevertheless, up to the fifth grade most of the work should be concrete; visual, auditory, or kinesthetic. By this time, however, the vocabulary has become more extensive and more strongly intrenched, so that verbal-motor imagery, either of the vocal organs or the hands, develops rapidly.

Too much word or verbal imagery may make mental life unemotional and stale, but without it there will be no adequate intellectual life. It can be cultivated by mathematics, grammar and other highly formal branches. Controlled objective imagination is a source of great happiness, richness, and power for good. It can be developed advantageously in children by imaginative literature, by story telling, dramatization, nature study, geography and history.* All these forms; visual, auditory, kinesthetic, and verbal, require specific cultivation, for they are the basis of constructive imagination to which the world owes its greatest debt; the debt to creative genius. It is difficult to say where the normal imagination ends and the abnormal begins. Sometimes children who are only three years of age live a large proportion of the time with imaginary companions, and in an unreal world, the keenness of their imaginations overwhelming the truth so that they are not able to discriminate between what is real and what is false. Usually this disappears, but sometimes it passes into pathological lying, and in children with neurotic tendencies, especially in those who have had an unhappy environment, imagination may be a source of serious danger, feeding the tendency of this type of child to create a world of fantasy, not logical nor based on fact, to which he can and does withdraw, thus putting himself out of contact with the adaptive difficulties of reality which are necessary for sane functioning and development. This may be potential dementia præcox, and should be recognized as a possibility in unhappy and habitually inattentive, non-coöperative children. It requires care in handling. The parents should provide playmates, both in the home and outside of it, and they should insist upon coöperation with them. Interesting material is also important in securing the child's attention, but the reading of much fictitious matter for this type of child is harmful. Responsible work, which is purposeful and largely physical, aids considerably, as does the establishment of habits of promptness, interference with every indication of day dreaming, and sometimes complete change of environment. Such children are usually delicate and require the most intelligent provision for rest and proper nutrition.†

Memory.—All images that come before the mind are preceded by an original sensation, perception, or idea which has made a sufficiently permanent impression to be capable of recall. The process of reproducing experiences characterizes both imagination and memory but in imagination the experience is colored in consciousness by the belief that it is unreal, while in memory belief accepts the reality but relegates it to the past. James' definition of memory is as follows: "Memory is the knowledge of an event or fact, of which meantime we have not been thinking, with the additional consciousness that we have experienced it before." This recognition of past experience is complex, involving "a general feeling of past* direction in time, a particular date conceived as lying along that direction (a date defined by its name or phenomenal contents), an event imagined as located therein and owned as part of my experience." The act of memory, however, includes not only the recall, recognition and orientation of data associated with experience, but it also includes the *effects* of experience or learning which have become permanent by the tendency of all situations to evoke the responses which have been connected with them.† Memory experiences, moreover, are not only accumulative but forever changing. Both nervous tissue and memory are modified by every new experience which occurs after the first impression is made.

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* See Colvin, "Learning Process."

† Meyer, Adolph, Preventive Mental Hygiene, Psychological Clinic, ii, p. 90.

It is probable that all experiences produce impression upon nervous tissue. Those that seem to be lost are stored away in the sub-conscious, some of them to function beneficently while others introduce anxiety factors which absorb attention that should be focussed entirely upon the memory material during the time that the process of memory fixation is occurring.

Impressions are fixed in two ways: By repetition or drill, and by association. It is necessary to learn some subjects, like spelling and the multiplication table, by the rote method, using the eyes, ears and the whispered voice simultaneously for reinforcement. Writing also is helpful in memorizing after it has become mechanical. Before this time it is a hindrance because the child's attention is divided by the effort required in the act of writing itself. Rote memorizing is uninteresting at best and involves the drudgery of drill, but this can be relieved by helping the pupil to see the advantage of it, by emulation and by other suitable reward. Drill has a distinct value of its own, because it produces conflict with greater interests. If it is followed by success, it results, as does all successful conflict, in stability and mental hardness.

Memory established by means of association is a much more effective method of fixing impressions than repetition. The more paths that lead to any given idea, the more meaning it acquires; the greater interest it secures. Teachers with ingenuity have the happy faculty of devising legitimate measures for increasing associations with an interesting bearing upon the work. They recognize the importance of using as many aids as possible and in so doing frequently double the rate of learning.

Space here is insufficient to elaborate the essential points in memorizing. The briefest reference only can be made to them, but the reader is referred to Colvin's "Learning Process," Chaps. 9, 11 and 12, or any other good Educational Psychology.

* Thorndike, "Educational Psychology," i, p. 193.

† *Ibid.*

Efficient memory conditions are concentration of attention, orderly association, freedom from hurry and nervousness, mental poise, and an attitude of leisure.

Meumann* designates four definite stages in efficient memorizing:

1. Attention is directed to the material and its general nature discovered.

2. The material is gone over passively (many stop here).

3. There is active control of learning by analyzing the material in the light of its associations.

4. The material is carefully reviewed, the salient points emphasized, and the whole organized on the basis of its associations. Outlines demonstrate the fourth point and show the advantage of "partial learning." The attempt to fix and retain all the items in ordinary subject matter is highly wasteful and less efficient in keeping on demand essential facts. There is, of course, some material, such as poetry, that requires verbatim learning. In memorizing material of this type, the child should be trained to go over the whole repeatedly, afterward bringing up the weak spots by especial effort.

Recall, without the immediate presence of the material, should occur frequently if it is to be fixed in the mind. Half the time should be so employed with the significant material, during which it should be not only re-imaged but re-instated in terms of the child's own thought. This produces definiteness. The real value of the recitation is its opportunity to reveal inaccuracies and haziness.

Memorizing should not be concentrated, but distributed, because it takes time for association processes to organize, and because long periods produce fatigue and inattention. "For the youngest children it is probably better to have any subject given at two different hours of the day, one in the morning, one in the afternoon." Older pupils, whose power of attention and interest are greater, get a better grasp of the subject as a whole by longer periods of study.

Experiments in memory show that association in learning is relatively poor in children, and that during the period of puberty it is especially difficult. Not until association processes are well established does memory become an easy process, and then it becomes progressively easier till full maturity is reached.

Attention.—The medical "field of vision" is analogous to the psychological field of consciousness in that there is in each a focal point under close scrutiny and sharply defined, and a margin or "fringe" in which objects or ideas are indistinct. Attention may be defined, therefore, as that type of mental activity which focusses intensely for a brief period upon a specific point of interest, either an object or an idea. James explains the narrowness of consciousness by the fact that the hemispheres act as a unit and that adjustments are made as a unit. If the mind attends, the body attends with it, attention in the final analysis being physiological. No better illustration could be offered than that used as an advertising medium by one of our popular phonograph companies: "His Master's Voice." The position of the ears and head, the expression of the face and body of the little dog, all show a remarkable unity of adjustment to a single idea. Now, as the mind attends to one idea only, or to ideas that have an organic unity, and as the environment changes constantly, it follows that attention is compelled to shift rapidly if it will keep up with the environment. The direction of the shift is due to interest which is the pleasure-pain tone that accompanies attention and directs the mind in its activity. Interest which is accompanied by the desire to know more is curiosity, and this instinct, both early and late in life, is the power that turns the lock beyond which mental progress proceeds.

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* Quoted by Colvin, *ibid.*

There are three kinds of attention: Involuntary or passive, voluntary or active, and a third which resembles the first because it also is held without conscious effort. In the first type interest holds the mind to the matter which is presented to attention. In the second it is necessary to summon the will again and again in order to force mental activity back to the point that requires consideration, because uninteresting material lacks the intrinsic elements that compel attention. In the third, mastery of the difficult problem has been attained, efficient habits or automatisms have been established, and a perfected performance then occurs without active attention. Modern educators have made every effort to interest the school child: capable teachers, play, objective projects, dramatization, a carefully established background as the basis for new ideas, the presentation of the same material from many points of view, happy surroundings, equipment that possesses intrinsic attraction or beauty, are all furnished as stimuli for passive attention. If the subject is uninteresting, attention at once becomes voluntary, either because ennui develops, or because new physical and mental adjustments must be made which produce conscious effort, or because there are distractions coming from without. No matter how good the teaching may be, the two latter factors will and should be encountered to a certain extent in the schoolroom. There must be some way, therefore, of overcoming the lack of interest and the external distractions. As has been said, the desire to know is instinctive. Eventually curiosity, self-esteem, emulation, constructiveness, fear, remote ends, all enter into the quest for knowledge, and hold attention. In early childhood, however, the immediate end, only, provides an incentive. It is the latter fact, together with a lack of the appreciation of values, that makes voluntary attention so difficult in early life. It is, therefore, very important in the kindergarten and earlier grades to secure attention through interest for immediate ends. As the child becomes older, voluntary attention should be cultivated. It is this type preëminently which, as has been said, trains the will, producing stability, hardness and strength. This is done by drill which can be accomplished without ennui, if the remote end, by which is meant the good that can be foreseen resulting from practice, is attractive and not too far away (Bagley). Charts showing the child's progress, emulation, money rewards, approval, punishment, etc., are further factors of importance to be used with discretion.

The establishment of habits of attention are absolutely necessary for logical thinking or success in life. Janet says that the gauge of the sanity of an individual and the measure of his mental efficiency is his power to attend to the present situation. Insanity, psychasthenia, neurasthenia demonstrate the truth of this statement. Many such abnormal conditions start in childhood, having physical bases such as hunger, the use of coffee or tea, ill-health, aching teeth or other pain, discomfort of eye-strain or headache, fatigue, or poor ventilation of the classroom, all distracting the attention. Not infrequently they are the result of "conditioned reflexes" or inhibitions produced by too much confinement or repression, or misunderstanding or unkindness in the home. Sometimes on the same basis physical practices or ideas which the child believes are wrong produce worry and conflict, and develop habits of distraction. Children with habitually relaxed bodies, full eyes, and expressionless faces should be under careful observation because it is imperative that habits of attention be restored. Such causes can usually be eradicated either by obtaining the child's confidence, followed by frank discussion and coöperation, or by placing him in an entirely new atmosphere. In either event, everything possible should be done to establish health, both physical and mental. Long hours of rest, wholesome food, fresh air, play and comradeship help in this connection, as they do elsewhere, and interest in new subjects is absolutely essential. Proper conditions for study are also necessary; study quarters should be quiet, light properly adjusted, furniture comfortable, materials to work with at hand before work is begun, and there should be regular definite hours for study. How frequently the teacher's statement that the child does not pay attention is passed over lightly, because parents and physicians are not alive to the ruinous consequences of divided interest.

The Higher Thought Processes. *Conception.*—Almost with the beginning of sensation, experiences begin to receive faint interpretations or meanings which grow more and more significant as they accumulate and play upon each other. "They spring out of the mind's effort to render distinct the various meanings with which it has to deal" (Angell). All efficient, honest research is eventually rewarded by hitherto undiscovered facts or ideas which finally emerge from the accumulation of related experiments. The infant's mind is a research laboratory working with psychic elements and objects, *i.e.*, sensations and perceptions, and their material counterparts which, on account of their inherent associations, become organized by means of experience, memory, habit, and voluntary muscular action into classes or groups. Each member of a specific group requires on the part of the child a specific adaptation, and from these accumulated adaptations the group derives a specific meaning. For example: If a slender, sharp-edged key is placed in an infant's hand, it will be grasped spontaneously, causing pain, out of which rises both a sensory and a motor experience.

Two or three repetitions of this, or perhaps less, will be followed by refusal when the key is presented again. This indicates some recognition of it as an object or percept, which has faint meaning. Sometimes after the fourteenth month, if the child lives in an environment where keys are familiarly mentioned and used, he will show recognition of the object when it is called by name. Before he is three years old he will use the name himself, indicating that his ability has now reached the point where he can convey definite recognized meanings in the form of symbols or language. The process has consisted to this point of abstracting and selecting from a mass of objects which have in common such qualities as hardness, weight, luster, smoothness and sharpness, a few specific characteristics, *viz.*, a particular type of form, material and function, which give them an entity, or especial meaning or significance. These particular outstanding features arouse the attention by means of the sensory organs, the conscious mind then adjusts the body to them in some way, and this adjustment results in incorporating them as more or less permanent mental furniture.

Angell defines "conception as that mental operation by means of which we bring together the common points of our various experiences and mentally consolidate them into ideas; ideas which we are then able to use as symbols or representatives of these manifold ideas." When the mind is associating a name directly with the object before it, the concept is sensorial and does not require an image. Most concepts, however, require a mental image of the thing perceived and a representative symbol, which makes it possible to use the image automatically. Such concepts are called verbal (p. 993). In the higher thought processes they become very abstract. For example: The concept "key" is not only used as a symbol to designate an object which unlocks material objects, but also represents forces that unlock difficult mental and moral situations. In the field of mathematics, abstraction is carried to such a point that all other characteristics of objects are submerged in the idea of units or groups of units. The value of the concept as an agent in mental development depends upon the association and classification of related objects and ideas, upon the process of discrimination, which is necessary in discarding elements in the concept which experience has proven to be false, and upon the reduction of confusion by drawing nice distinctions in choosing the right word.

The best training in concept formation, therefore, involves, first: definite experience in the classification and organization of sensory and perceptual experiences: form, color, size, dimension, and specific objects (article on Play, p. 1072). The normal child should be able to discriminate size in the larger and smaller blocks with which he plays at the age of three. At four he distinguishes form and linear dimension; at five or earlier, color. Sensory training of this kind he receives in the kindergarten. At six, or before, children are trained in phonics by which words or concepts are classified on a basis of form or related sound. The "at" family is a typical example of classification by sound: r-at, f-at, c-at, etc. Number work, which is the beginning of the science of groups also presents opportunities for training in number concepts. Here we have practice in association and discrimination and abstraction; the latter, as has been said, attaining its highest degree in the concepts of number. Second, if knowledge is to be really incorporated, it is essential that ideas be actually experienced. For conceptual development the careful scientific study of a neighboring river is of greater value than any information about it, that can be derived from books. As far as possible, children should be given the privilege of first-hand thorough contact with natural phenomena (Dewey), and not made to depend upon description or language. Third: through association, further conceptual development may be produced by bringing the child's mind in contact with interesting facts and materials gathered from remote, as well as nearby, places.

Such schools as the School of Education of the University of Chicago, the Francis Parker School of Chicago, the Horace Mann and Ethical Culture and Lincoln Schools of New York, and the Park School of Baltimore are furnished with elaborate visualizing apparatus and descriptive equipment in accessible form so that the children may handle and assemble and demonstrate meaningful material in connection with language work and with their social branches, such as history, geography, etc. In contrast to this is the great group of sectarian schools in which the equipment for teaching the social branches is very meager and the English language is relegated to a secondary place. In rating the latter group of children mentally on the Binet scale it is customary to allow them two additional years for their language defect.

Judgment.—Before an infant has reached the age of 24 hours he has formed a vague judgment regarding the efficiency of crying in relation to the satisfaction of hunger. This is based on reflex act, instinct, sensation, crude perception and external response or experience. Today's action therefore is the result of yesterday's manifestations of approval or disapproval, satisfaction or dissatisfaction. As the infant's mind at birth is almost wholly unorganized, it is only by means of discriminative experiences such as these that, little by little, the nebulous state begins to clarify. As experience supplies material for perception, memory and imagination, there is a gradual emergence of clear-cut, definite, *single* ideas eventually crystallized into meaning through the agency of adjustments and symbols, concepts, or words. As experience advances farther, related concepts, either two or more, are placed together in the form of statements or sentences, and judgments are formed.

Angell has defined the beginnings of judgment as the assertion of a relation between mental elements. Judgment, to be valuable, must be based upon personal experience which the individual knows to be true. The wider the experience, the more sincere and genuine the contacts with life, the more comprehensive and honest the individual's dealing with his own consciousness, the more dependable will be his judgment. Development in judgment depends upon struggle to know the truth. Doubt is the factor that exercises the higher mental processes, judgment and reason, because it lifts the mind above the ordinary stereotyped reactions into thought crises, producing a critical analytic-synthetic attitude, whose tendency is to compare and systematize data into such relations that a valid conclusion may be reached. As judgment is the most important agent in building up and organizing the mind, it can be seen that it is an essential function of the teacher to raise doubts in the minds of the pupils which demand the disentangling of vague material so that the original, basal constituents may be brought into view, considered and combined or separated on their merits. In this way correct judgments are formed, resulting in new and better concepts and in habits of organization. It is of the greatest importance that thinking shall accompany all that the child does. "Mere activity is stultifying. Mere discussing and planning is usually debilitating. Without intelligent action there will be no growth in character" (Hartshorne).

There is a type of indecision which is pathological, occurring most frequently in neurasthenia and psychasthenia. It is probable that early, habitual training in judgment, and definite conclusion with action to correspond, would establish such habits of mental control that the disablement of the above diseases might be precluded by positive, orderly decisive habits of mind and body, established in childhood.

Reason.—Every sensation, perception or idea that is impressed upon nervous tissue produces a reaction in the form of motion. The repetition of the same or similar stimuli establishes an association of ideas through the agency of habit necessitating a motor or bodily adjustment. If a certain idea or group of ideas always produce the same or similar responses, a feeling of permanency becomes established in the mind in regard to them. Habitually related ideas, producing habitually related responses come to form a basis or principle for comparison, from which conclusions or judgments regarding any single member of the association can safely be drawn. This process of deducing specific single conclusions from the content of the related group or principle is known as the *deductive process of reasoning*. While this is going on, the principle is being strengthened or weakened by the constant application of new ideas, which are introduced to the old, compared with them, and accepted or rejected, as evidenced by the nature of the response to the idea. The new idea may be rejected because the relation is antagonistic or too remote. In this case it will either be dropped entirely, or it will form a new nucleus around which a different group of related ideas gather from which a corresponding new principle may be induced. This process of abstracting a principle or general idea from many related specific, single ideas is known as the *inductive method of reasoning*. After the new principle is established, it in turn becomes a basis for the deduction of further ideas, as in the former instance. In each case advance is made by the examination and comparison of separate, particular ideas in the light of some result which is sought. This process, called reasoning, involves not only the truth, as in judgment, but "How shall we arrive at it? What is the cause and what is the effect?" In other words, it is thinking problematically with a purpose or with a clearly defined end in view, which attention holds steadily before the mind until the conclusion is reached. The solution of the problem is attained by means of some guiding idea or clue found in the situation. Reasoning is abstraction carried to its highest point. If there were no preceding organization of experiences into concepts or symbols, reasoning would never occur. It is because association and discrimination have already abstracted the distinguishing features of related perceptions and set closely allied ideas and experiences off by themselves that the abstractions characteristic of reasoning are possible. A very simple instance of reasoning is found in the Binet-Simon problem "If 1 yard of cloth costs 15 cents, how much would 7 feet of cloth cost?" the controlling idea or clue is the cost of 1 foot of cloth, attained by means of the number habit, division. With the clue clearly in mind the application of the number habit of multiplication leads to the solution of the problem. Another instance may be represented by a bunch of keys, the problem being to unlock a door. One key, or hypothesis, after another is tried by the trial and error method, and results in failure. Finally, the key and the lock are inspected and compared, and it is observed that there are certain corresponding ridges which differentiate them from other keys and locks and probably furnish the clue. Thus the solution is obtained by the search for a distinguishing feature, by comparison and by deduction based upon previous experience. Dewey outlines the process of logical reflection thus: (1) A felt difficulty. (2) Its location and definition. (3) Suggestion of a possible solution or clue. (4) Development by reasoning of the bearings of the suggestion. (5) Further observation and experiment, leading to its acceptance or rejection.

An open mind is extremely important in fruitful reasoning, but beyond all other factors is the ability to discover the clue which usually requires invention: the highest attainment of the mind of man.

In discussing reasoning among children, Colvin* quotes Bonser, who studied the children of the fourth, fifth and sixth grades to determine their reasoning ability.† He found that there is a gain from grade 4*A* to 6*A* for the boys of 338.77 per cent., and for the girls of 246.15 per cent. The boys reach a maximum in median ability in the period from 11 to 12 years, the girls from 12 to 13 years. Beyond the maximum there is a decline in ability for both boys and girls, the ability for boys being less from 13 to 14 than from 11 to 12. Both sexes advance after the decrease.

If the process of reasoning is to be developed it is important that every lesson involving distinct issues should be approached with the purpose clearly in mind. A little more consciousness of the Conan

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* The Learning Process.

† Teachers' College, Columbia University, Contributions to Education, No. 37, New York City (1910).

Doyle type might be a distinct aid in opening the eyes of school children to the importance and use of clues.*

Emotion.—Reason does not appear until life becomes complex, until explanations for behavior are necessary, until there are a number of possibilities which confront the experimenter, until doubt enters the field. The higher in the scale of intelligence the individual advances, the more his judgment weighs matters and the less intense become his attitudes and reactions because the personal element disappears as these processes take place.

Emotions, on the contrary, are manifested at the very outset of life, springing out of instincts possessed by all organisms which have passed the vegetative stage. It is these instincts that produce the emotions, desires, and tendencies of the personality, give man in large part his propelling power, set the main trends of character, and furnish him with inspiration for good or evil. As far as behavior is concerned, they are vastly more important than intellectual power. In children, particularly, they furnish the impetus that helps them to stand by difficult problems till they are mastered.

There have been a number of theories in regard to the genesis of emotion. Many psychologists advocate the idea that feeling occurs first, and is followed directly by a motor response of some kind. On the contrary, William James and others have formulated the hypothesis that personal excitants instinctive in origin act first by stimulating the fundamental reflexes, thus producing physical states which in turn arouse the feeling or emotion. "Any emotion," says James, "without the corresponding bodily state would be purely cognitive in form; pale, colorless, destitute of emotional warmth." Recent discoveries connected with the endocrinous glands and the sympathetic nervous system bear testimony to the validity of this theory, but it is still unsettled.†

McDougall's‡ list of emotions is as follows: Fear, disgust, wonder, anger, positive self-feeling or elation, negative self-feeling or subjection, tender emotion, admiration, gratitude, scorn, loathing, envy, reproach, anxiety, jealousy, vengeful emotion, bashfulness, shame.

Watson's laboratory investigations with very young infants§ show that the multitude of emotions manifested in adult life are the by-products of three great original emotions, fear, rage, and joy or love, and are developed by "conditioned reflexes," to which reference has already been made (p. 978, etc.). The latter Watson illustrates as follows: Nearly all children have a fear of loud noises like thunder. On the other hand, they are entirely indifferent at first to brilliant flashes of light. It is the habitual association of the two that produces a secondary fear of lightning. If a non-emotional experience occurs repeatedly in connection with an emotional experience, the former derives a permanent color of pleasure or pain even when detached from the latter. It would seem, therefore, as if a large amount of our feeling life were secondary and the result of association and habit, a fact bearing upon the development of behavior which is incalculable.

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* Colvin: "Learning Process."

† Thorndike, E. L., The Original Nature of Man, Educational Psychology, i; Crile, G. W., "The Origin and Nature of the Emotions," W. B. Saunders and Co., Phila. (1915); Cannon, W. B., "Bodily Changes in Pain, Hunger, Fear and Rage," D. Appleton and Co., N. Y. (1915).

‡ "Social Psychology."

§ Watson, J. B., "Suggestions of Modern Science Concerning Education," Jennings, Watson, Meyer and Thomas.

Sometimes an unhappy emotional experience organizes itself into a complex which is then buried in the subconscious and forgotten. It is by no means dead however, but expresses itself by mal-adaptation both in thought and outward act. Thus again, painful emotion is a serious determinant of behavior.*

There are four fundamental, biological tendencies or types of desires that appear at all ages in varying manifestations, *i.e.*, desire for new experience, for mastery, for recognition and for safety (p. 982). New experience involves the instinct of curiosity which initiates the pursuit of knowledge. The child's desire to have his own way is an expression of mastery, is a conditioned reflex from anger, and involves an enormous amount of feeling. The ego instinct is further revealed in the individual's desire for recognition, and his desire for safety is shown in the instincts of fear, jealousy, envy, rivalry and others.

Emotional abnormality usually begins very early in life. Faults of the disposition which are fundamentally emotional are due far less to the native equipment of the child than to the ineffective parent or disordered family life. Such faults profoundly affect the mental and physical life of the individual. Sustained, easily controlled attention, for instance, can only be developed under good emotional conditions. The feeling of success which is almost absolutely essential to progress is denied the child whose attention is divided between his work and the under current of accompanying emotional protest within himself. Psychopathic and inferior personalities result. Chronic strain and fatigue result terminating in neurasthenia, psychasthenia, and some of the more serious psychoses, and a great host of the moderately inefficient who have good native equipment. The seriousness of irregular biological habits, of nagging, of excitement, of early sex conflicts, is only realized by workers in Juvenile Courts, clinics for peculiar children, and institutions for the insane. There should be more emphasis placed upon these matters in medical and theological institutions, in normal colleges, in parent-teacher associations, in the adult Bible classes and guilds of churches, in women's clubs, and other like organizations. Parents should be taught the importance of establishing early biological habits in their children: habits of regular eating, sleeping, regular play, work and waiting habits; habits which compose the "mechanism of morality." They should be taught the seriousness of nagging, of too much repression, of over-excitement, of conflict in the home, and of using fear as a factor in punishment. Mental states have been produced by "The Bogie Man" that nothing can eradicate.

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* Thom, Douglas A., "Habit Clinics for Children of the Pre-School Age." The American Jour. of Psychiatry, ii, No. 1, July, 1922, or Mental Hygiene, vi, No. 3, July, 1922.

Volition.—One of the original tendencies of man is spontaneous activity. At the very outset of life the stimuli received give rise to diffuse spontaneous muscular action—impulsive and uncoördinated. Muscular equipment provides for every motion both a protagonist and an antagonist, so that conflict is inherent in movement. Development of control does not proceed equally in all muscle groups; it proceeds now more rapidly in one, now in another, and the problem of control is centered in an attempt to coördinate and systematize movements into a performance which has a conscious end in view. This is the beginning of volition or self-control. If the child succeeds in securing this coördination so that his end is gained, he establishes the beginning of an efficient satisfying habit. Very early, children learn either to emotionalize or to control themselves in relation to their biological experiences, for they learn not only by means of systematized muscular coördinations, but also by means of other essential, primary habits, such as eating, functioning, sleeping, playing, waiting, etc. Children are the victims of their own impulses at this period and at later periods, unless simple codes or family rules are established and adhered to. Play is another type of activity which brings about intelligent control. Children under the age of four pursue their ends through play with as great intensity, persistency and purpose as adults. After this age it should be the aim of parents and teachers to assist childen to use their imaginations intelligently in choosing their purposes, and to see that they carry them through. Choice implies pursuit, and successful pursuit requires control. This is difficult at first, therefore interesting material and standards by which the child can measure the result of his pursuit are of great value as incentives.

It adds to the wholesomeness of the situation if the child's motives can be made to center interest not in himself and his performance, but in the undertaking, for "no man liveth unto himself." Before a child is four years of age, if conditions in the home are normal, he has been obliged to regulate his desires in such a way as to conform to the desires of the family and, by so doing, has learned coöperation. At five he should be able to adjust himself to children outside of the home; and the year following he enters school, which brings with it a myriad of new adjustments, and increases immeasurably the necessity of adaptive control. Now both normal development and happiness depend in large measure upon cöoperation. It becomes necessary, therefore, to direct the imagination to the public opinion and welfare of the group. If coöperation within the family has already become habitual, it is relatively easy to secure it in the larger relations. Normal religious training has definite significance here.

There are two fundamental religious attitudes: faith in and obedience to a moral, loving, supreme person—God. These attitudes are powerful because trust produces peace and intelligent cordial obedience frees the spirit from emotional self-domination and self-seeking. Desires and impulses are inhibited where situations require inhibition and at the same time the mind is at liberty to consider the essential elements of situations that confront it. As has been said before, normal, mental activity is blocked in behavioristic types of children by unhappiness caused by emotional memories and desires. It will probably be found eventually that a large number of moderately retarded and delinquent children owe their retardation and delinquency to emotional distraction and weakened volition which it is possible to overcome in large part by trust in God and man and habits of obedience.

As the benign will of a human father furnishes the child with a settled idea of love and justice and order, of someone who understands and helps him extricate his confused emotional experiences and adjust them to life, so the idea of God, through the growing social circle furnishes the larger ideal of love and justice and order, of understanding and help. Thus recognition, and allegiance to a greater Will constantly organize and unify chaotic tendencies that hurt the child's spirit, by substituting a conception of group needs for the individual need, of self mastery instead of the mastery of others, of love of giving instead of love of getting, in this way sublimating conflict and establishing self mastery and peace.

Character.—A ten and a half year old boy, when asked the difference between character and reputation, replied: "Character is what you are, reputation what people think you are. You might pretend, and be just awful on the inside." This definition implies the necessity of an essential correspondence between instincts and habits, their action and reaction. Character implies sufficient unity and stability in the individual so that reactions can be foreseen. Its fundamentals are instincts, tendencies, impulses, desires and feelings. The following is a summary based partially upon Ribot's classification of character* types which he says have their source in the feelings and the will. The relative proportion of components of this character classification determine to a considerable extent the type of the individual. The classification is as follows:

1. The sensitive or emotional group,
2. The group which expresses itself in action, and
3. The intellectual group.

1. Emotional types are represented by two general tendencies:

(a) *Schizophrenic*
Repressed egoism
Hypersensitivity
Inability to stand criticism
Attacks of irritability
Shyness
Tendency to with-draw within himself; "shut-in personality"
Over imaginative
Day dreaming

(b) *Cyclothymic*
Flamboyant egotism
Alternating periods of elation or depression (way up or way down)
Not steady in application to work nor in quality of work.

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* The Psychology of the Emotions.

Obstinacy
Selfishness
Unwillingness to cooperate
Indifference to the suffering of others or to the outcome of his own behavior.

Individuals of the schizophrenic type are extremely susceptible to impressions from within. Though they are ordinarily introspective and not constructively active, they are occasionally represented by geniuses who are temperamental and work brilliantly in spots. This is the type which finds social adaptation difficult and therefore as all vocational guidance bureaus testify, often "out of a job." Dr. Herman Adler's study of unemployment and personality; (Adler, Herman, "Unemployment and Personality," Mental Hygiene, i, No. 1, Dec., 1922) and ("Psychiatric Contribution to the Study of Delinquency," Adler, Herman; Jour. of the American Institute of Criminal Law and Criminology, viii, No. 1) makes this very clear in contrast with the social and economic reactions of the cyclothymic type, which on the whole while less efficient economically are much more adaptable socially and therefore in all situations more agreeable.

2. Action type;
Activity is incessant and usually trivial
Thoughtless (pure type) in regard to outcome of his activities
Impulsive
Loves to torment and tease
Not methodical

Members of the active type are as a rule nervously and physically robust. Many of them are not in the least intellectual and their energy finds expression in external activities that are not significant. When, however, intellectuality is combined with physical energy it produces an executive type, sometimes of notable power, which Ribot says usually expresses itself in some form of conquest. Pasteur is cited by Thomas as a personality of this type.

3. Intellectual type;
Calculating as to the result of his actions
Often intrinsically selfish
Is not emotional
Is not very active.

Pure intellectuals are ordinarily represented by individuals in whom there is very little sensitivity and very little physiological activity. They are apathetic, unmoved by sentiment, never jump at conclusions but carefully calculate all situations. Scholars and scientists of which Benjamin Franklin is representative, are not infrequently of this type.

Fortunately they as well as the preceding types usually possess other characteristics which produce better balanced personalities.

These three types when unmixed are true characters because they have "unity and stability," *i.e.*, they are always consistent. Pure types are uncommon, the characteristics of most individuals being more or less heterogeneous. A mixture of types is not only compatible with normality, but is undoubtedly better, if the mixture is such as to produce balance. The fact must not be lost sight of, that such mixtures may produce an incoherency which results in the appearance of duplicity; and further, that either pure or mixed types may produce individuals who are definitely defective and unstable. Such are the moral defectives or anti-social group who are controlled by their impulses, and the amorphous group who are almost altogether the product of their environment; emotional and moral will o' the wisps.

Children have the same characteristics as the amorphous group, but it is because their instincts are capricious, their desires as yet uncoördinated, and their wills undeveloped by conflict. In considering behavior we have to deal with the following:

Behavior.—(1) The biological tendencies of the race; habits of eating, waiting playing etc.

2. The specific instinctive tendencies of individuals.
3. Their prevailing moods.
4. Their capacity for education.
5. Their environment.
6. The methods to be employed, or treatment.

1. A brief statement of biological equipment has already been made.

2. It has been shown* "that any single individual may produce 4,096 different combinations of character, and the number producible by two given parents runs up to more than 500,000." This fact points to infinite variety in man and to the necessity of studying each child in order to learn what he has and what he lacks. It is of the utmost importance that the training of good instincts and the pruning of harmful instincts be instituted early, so that the child's particular weak points be developed into strong ones or counterbalanced by tendencies that will compensate for them. No child can be organized into his best possible output unless his instinctive intellectual and emotional equipment is understood and his volitional possibilities developed by proper training in habits. In no realm of life has there been so little intelligent effort to get at the fundamental facts of any undertaking as in the undertaking of educating children for life. Both in the family and in the school they are still lumped together as if they were all cast in one mold.

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* Jennings, Watson, Meyer and Thomas, "Suggestions of Modern Science Concerning Education."

3. A most excellent article has been written by Hoch and Amsden* which throws much light on the prevailing moods of children. It also considers problems of inheritance, of beginning psychosis, and of abnormal and nervous children. The authors discuss the child's equipment in regard to common sense and intelligence, the output of energy, the subject's estimate of himself, his power of adaptability to his environment, his customary moods, his instinctive demands, his general interests and pathological traits. They bring out such characteristics as self reliance, self depreciation, tendencies that interfere with contact with the world, such as sensitiveness, shunning society, etc., selfishness, jealousy, frankness, reticence, conscientiousness, and over-conscientiousness, ability to shape one's circumstances, leadership or its opposite, habitual or episodic reactions of elation or depression, irritability, sex instincts, capacity for sublimation, or getting satisfaction from altruistic interests.

A recent article entitled "The Use of Experimental Psychology in the Practice of Medicine"† throws much light on methods of obtaining objective scientific data concerned with specific properties of the brain and nervous system, tests for vasomotor reactions, pain and suffering, memory, flight of ideas, effects of suggestion, etc.

4. Probably the best single method for obtaining information in regard to a child's capacity for education is the Binet-Simon Scale. This comprises a series of tests aimed at measuring the intelligence of individuals. It is very widely used and has proven to be reasonably reliable. In a book entitled "Measurements of Intelligence" Terman gives careful instruction which anyone who has had some training in psychology and some experience may use. It should be emphasized that a foundation of psychology is necessary if the tests are to be properly interpreted, and that no one unfamiliar with psychology should use them. The examiner usually expects to find retardation, because children brought for examination are generally below grade or functioning poorly in the proper grade for their age. It happens occasionally that non-assertive brilliant children of the sensitive type are making a failure of school work, or getting into habits of day dreaming, or petty immorality (lying, thieving, etc.) because their exceptional equipment has not been recognized. The author has in mind one child whose chronological age was 10 years 6 months, and his mental age 17 years 9 months; another 13 years and 17 years 6 months respectively; another 12 years and 17 years 4 months respectively. Many of these cases are due to suppressed energy, or to a lack of interest in puerile subject matter, etc., both of which are retroactive. On the other hand, some children with very high intelligence quotients, are not capable of functioning well in school or society, perhaps because they are too sensitive, or too fantastic in their ideas, or because they are unable to organize their mental processes effi-

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* August Hoch and G. S. Amsden: A Guide to the Descriptive Study of the Personality, New York State Hospitals Bulletin, vi (new series), (May–Feb., 1913–14), p. 344.

† Jacobson, E. J., A. M. A., lxxvii, No. 5 (July 30, 1921), p. 342.

ciently, or because they lack balance in some other direction. In any event such cases add weight to the supposition that every school child should have an intelligence test.

Summary of Capacities, Character and Environment

		Desirable Characteristics	Undesirable Characteristics
	Physical equipment:	(See medical card)	
	Reflexes conditioned:		
	Instincts:	Multiform physical activity.	
		Multiform mental activity.	
		Fear resulting in caution.	Fear resulting in cowardice.
		Pugnacity.	Fighting?
		Curiosity.	
		Imitation.	
		Play.	
		Collecting.	
		Joy and singing.	
		Tendency to form efficient habits.	
	Sensation Perception	(See Summary under School):	
	Dominating habits:	Regular biological habits: Eating, sleeping, playing, waiting, etc.	Irregular biological habits.
		Orderliness, obedience, steadiness of application in work.	Confusion, disobedience, flightiness.
	Attention:	Involuntary.	Distracted attention.
		Sustained voluntary.	
	Imagination:	Based on fact. Productive.	Fantastic.
	Memory:	Visual, auditory.	Poor; natively.
		Rote, logical.	Poor; due to sickness, fatigue, or disease.
	Association:	Well related, rich, direct	Meager, heterogeneous.
			Dissociation.
	Higher mental processes:		
	Concepts:	Clear and comprehensive.	Inadequate and confused.
	Judgment:	Discerning and solid.	Lacks keenness and shallow.
	Reason:	Logical.	Inability to classify, to discern natural sequences, and to find clues.
		Uninfluenced by secondary motives.	Biased.
	Emotion:	Loving and joyful, sense of humor.	Fear, anger.
		Moods; optimistic and cheerful.	Moods; despondent, anxious, sulky, resentful, complaining.
	Volition:	Prompt decision.	Indecision.
		Right habits of self-control.	Obstinacy.
PERSONAL	Character type:	Sensitive—subjective.	
		Active.	
		Intellectual.	
		Amorphous; influenced by environment.	
		Mixed; with one predominant.	
	Behavior:	Thoughtful, good common sense, well-controlled, kind, prompt, dependable, orderly, honest, adaptive obedient.	Apathetic, restless, obstinate, violent, quarrelsome, procrastinating, cruel, lies, cheats, steals, profane, truancy (school, home), out nights.
		Character of books read.	
	School:	Sensory efficiency: Visual, auditory, kinesthetic.	
		Motor efficiency: Accuracy, strength, coördination.	
		Motor efficiency: Reading, writing, drawing, finger and vocal coördination (singing), games, athletics.	
		Speech defect.	
		Result of Binet-Simon test: Chronological age. Mental age. I.Q.	
		Rank in reading: Oral.	
		Silent.	

PERSONAL

Rank in: Spelling.
  Language and composition. (Trabue Completion Tests.)
  Writing.
  Number work.
  Drawing.

Causes of retardation:
  Mental: Immaturity, inability to study, lack of power of attention, application, perseverance, carelessness, poor memory or reasoning, timidity, discouragement.
  Wrong attitude: Dislike for school work, indifference, disobedience, dishonesty, day dreaming.
  Physical condition: See medical card.
  Irregular attendance: Due to personal or family illness, poverty, or non-coöperation of home, truancy, absence from city.

SOCIAL

  Environment: Language used at home.
    Language used at school.
    Backwardness due to late start.
    Change of schools within system.
    Change of schools without system.
  Administration: Inflexible grading. Poor preparation.
    Standards too high. Overcrowded class.
    Poor or nervous teacher.
    Teacher and pupil incompatible.
    Course of study too difficult.

Instincts:
  Play, imitation, adaptability.
  Seeks companionship, coöperation.
  Tendency to conform to law.
  Tendency to regard a higher power.
  Ambition.
  Pride.

  Jealousy.
  Embarrassment.
  Shame.
  Egotism.
  Pride.

Environment: *Home conditions:*
  Parents: Who dominates? F. M. Method:
  Step parents: F. M. Non-support.
  Parental neglect. Misunderstanding. Inefficient control?
  Subject's relations to siblings: Subject brighter, retarded, overbearing?
    Siblings brighter, retarded, overbearing?
  Boarders: Men. Women.
  Poverty: Weekly income.
  Untidiness.
  Housing: Number of rooms. Number of tenants. Light and air. Open windows at night. Toilets.
  Church connections: Attend Sunday School.
  Associates: Club. Boy Scout. Gang.
  Amusements: Movies.
  Leisure time: How spent?

Diagnosis.—To obtain a comprehensive, definite, and working picture of the child, underscore the items in the summary which are characteristic, and arrange them in groups corresponding to the groups in the summary, *i.e.*, physical equipment, instincts, habits, etc. In diagnosing behavior it is important to have a clear understanding of characteristics that indicate normality: The behavior of the normal child is happy, orderly, obedient, truthful, controlled, well-poised. He faces reality with up-standing courage, takes advice from others and criticism without flinching, and to a considerable extent controls his feelings by intelligence.*

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* Hamilton, Margaret J., Mental Hygiene and the Parasite, Mental Hygiene (Jan., 1921), p. 46.

In diagnosing the behavior of a peculiar child it is important to ascertain the following points:

1. Is there any focus of infection, physical discomfort or pain (tonsils, adenoids, teeth, eyes, ears, malnutrition, anemia or chronic fatigue, hysteria, chronic irritability headaches, epilepsy, night terrors, chorea, or post influenzal nervous disturbances? Is there tuberculosis, diseased heart or kidneys?

2. Are there any harmful physical habits: Too little sleep, too little or too much, or irregular or unwise food, such as coffee, tea, etc.? Are there tics or vicious habits?

3. What does the teacher report in regard to habits of *behavior in school?* Is he obedient and orderly? In what is he interested? If he has a difficulty in school work, what does the Binet Scale show? If there is trouble with number work, is it due to lack of facility in number habits (number combinations, addition and subtraction, multiplication and division), or is it due to lack of logical reasoning? Is there a reading, spelling or language defect? What is the atmosphere of the schoolroom? Does he like his teacher? Did he like his other teachers? Is he a truant? *If so, why?*

4. What are the *conditions in the home?* Is there poverty? What are the family habits—sleeping, eating, control? Who dominates the home, and how? If it is run at loose ends, whose fault is it? What is the behavior and mental status of the other children in the family? A yielding nature in constant contact with a bully, a bully undisciplined either by his parents or another bully in the family, or a dull mind which is under habitual contrast with a brilliant mind in the same home, or a child hopelessly incompatible with nervous parents or brothers or sisters would be better off in other surroundings. Dr. Norman Bridge* seriously suggests that in some instances it might be better to exchange children. Workers with abnormal and peculiar children find that the greatest stumbling block to progress is inefficiency, instability, lack of self-control or indifference on the part of the parents. The father is often found to be a tyrant—blind to everything but his own desires; the mother may be weak, constantly yielding to the child's harmful demands, or she may be strong but thwarted by the father, the grandparents, or other relatives. The intelligent parent who has the confidence of his child is in a strategic position to understand and to develop or change his specific instinctive tendencies because he has had experience with family peculiarities that lie behind the child's difficulty. He is in a position to alter the environment, and constant propinquity gives him the opportunity to establish proper habits of behavior.

5. What is the environmental situation *outside of the home?* There may be the gang, literature and movies; the latter based and not based on reality, in either case perhaps equally bad. There may also be contact with dishonesty, with sex evils, with violence and crime.

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* The Blind Side of the Average Parent, House Health.

6. What are the *personal characteristics?* Has the patient abounding *energy* and *initiative?* Does he do what others do, is he rebellious toward conventions, or does he show a tendency to choose his procedures with intelligence and independence, and to create efficient situations, making himself react properly to them? What is his *inner emotional life?* Is there any hidden conflict between desire and duty? If so, *what is it?* Has there been any early sex experience or abnormal experience of any other kind that has produced a complex which unconsciously affects his behavior? Again, *what is it?*

Are there *thought mazes* or habitual *indirect associations?* Does the child show little interest in his surroundings; does he live in a world created by his own fancy which is different from the world about him, thus making himself less adaptable to reality? Does he shut himself away from others? Is he reticent, passively stubborn, hard to influence? Is he over-sensitive, over-conscientious? Awkward and helpless in society, self-conscious, easily upset?* In short, does he show signs of dementia præcox? On the other hand, is he masterful? If so, is it because he is energetic, brilliant, born to lead, or is his domination coexistent with unwarranted egotism, with cruelty and stupidity? The latter may indicate a paranoid tendency.

There can be nothing haphazard in the study and diagnosis of character. Virtues and faults are specific, and habits of behavior are specific. There are also specific events, usually found to have occurred in the early nascent period of habit formation, which are sometimes within, sometimes outside human control, determining the prevailing emotional trends in the individual from childhood to the grave. It is most essential therefore to recognize and bring out into full light these intrinsic determiners, because they too, if understood and properly handled, can be brought under control.

Treatment.—The diagnosis and treatment of physical handicaps has been dealt with elsewhere in this article (pp. 928 to 977). Their importance is so apparent that it is not necessary to stress the matter. *Instincts:* As has already been noted, over-activity of such instincts as fighting, teasing, tormenting, bullying, fearing, jealousy, rivalry, embarrassment, shyness, secretiveness, acquisitiveness, greed, display, suggestibility and egotism, is harmful if allowed to develop. Control of these tendencies can be secured by suppression, but this treatment sometimes results in repressions and conflicts that do great harm. It is better, therefore, to find outlets for the energy manifested through other channels. What satisfyers can be used? The instinct of greed, for instance, can be overcome by eliciting the child's practical sympathy in case of genuine need. When he sees happiness and well-being substituted for distress and suffering by means of his own personal sacrifice, he may, after a number of experiences, make a permanent transfer to the higher social instinct. To the same end Nature affords repelling illustrations which can be used to help in mastering cruel impulses, such as the destruction of the weak by the strong. Such instincts may be harnessed by placing definite responsibility for the group upon the shoulders of the tormentor, because children like responsibility and usually rise to it. Fear may be overcome by taking pains to show the child the nature of what he fears, and by making him believe that the one dealing with him has great faith in his native courage. Good habits are encouraged by such books as "Fables," Æsop. "Adventures of Pinocchio," Carlo Lorenzini. "Children's Book," Horace E. Scudder. "The Princess and the Goblin," George MacDonald. "King of the Golden River," John Ruskin. "Fanciful Tales," Frank R. Stockton. "The Wonderful Adventures of Nils," Selma Lagerlof. "Black Beauty," Anna Sewell. "Careless Jane," Katherine Pyle. "Lazy Matilda," K. Pyle. "A Child's Garden of Verses," Stevenson. "Understood Betsy," "Dorothy Canfield. "Clematis," B. B. and Ernest Cobb. "The Sandman; His Farm Stories," "Bobby and the Big Road," Maud Lindsay. "Donkey John of the Toy Valley," Margaret W. Morley. "Heidi" J. Spyri. "At the Back of the North Wind," George MacDonald. "Kingdom of the Winding Road," Cornelia Meigs. "Garden behind the Moon," Howard Pyle. "John of the Woods," Abbie F. Brown. "What Katie Did," Susan Coolidge. "Tommy and the Wishing Stone," T. W. Burgess. "More than Conquerors," Ariadne Gilbert. "Sara Crewe," Burnett. "Secret Garden," Burnett. "The Man without a Country," Hale. "The Goops," poems of patriotic and moral nature, and fairy tales with indirect morals.

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*Hoch, Aug., Constitutional Factors in the Dementia Precox Group, Review of Neurology and Psychiatry, viii (1910); Bleuler, E., Artistic Thinking, American Journal Insanity, lxix (1913), p. 873. Hoch, Aug., Constitutional Factors in the Dementia Precox Group, Review of Neurology and Psychiatry, viii (1910). Hart, Bernard, "The Psychology of Insanity."

Josephine Jackson and Helen Salisbury, "Outwitting our Nerves," and Elida Evans, "The Problem of the Nervous Child," and W. A. White, "The Mechanisms of Character Formation." "Mental Conflicts and Misconduct," William Healy.

Habits which are harmful, or good habits poorly acquired, give way to orderliness and efficient adjustments not by nagging, but by patient training and should begin at the outset of life (p. 985). It is important to summon the child's imagination and his play instincts to help him over places that are too rough and difficult to acquire habits easily, but it is desirable to discard artificial props as early as possible and help him to realize the value of good habitual coördinations whether they be physical, mental or moral, personal or social.

A very successful experiment in habit formation is being carried on in a Habit Clinic* in connection with the Out-patient Department, Boston Psychopathic Hospital.

A word should be said about the habit of coöperation, which is unnatural to little children. It arises first through their attempts to please their parents, then by the favorable results that are produced as the result of pleasant contact with sisters and brothers, the servants, etc., then by learning that they are more likely to get what they want from others by helping than by hindering, and finally that there is an inherent value in adjustment to the larger group.

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* Thom. D. A. "Habit Clinics for Children of the Pre-School Age." Mental Hygiene, vi, No. 3, July, 1922.

The treatment of attention, imagination, memory, association, and the higher mental processes has already been discussed under their separate headings.

Emotion.—If the bulk of human emotional development depends upon instincts and conditioned reflexes, *i.e.*, the outgrowth of the association of non-emotional experiences from emotional (p. 979), it can be readily seen that emotional control must begin early. It has been stated (Hoag) that three-fourths of all nervous diseases, most of which are genetically emotional, arise in childhood, and that two-thirds of all adolescent insanities are manifested in some degree between the ages of 6 and 14. Most of the emotional experiences of childhood have their origin, either directly or indirectly, through the ego or self-preservative instinct, commonly manifested by fear and anger, love and joy. Burnham* states that normal activity for a child on an occasion of fear, perhaps the most potential for harm of all the emotions, is either to run away from the object causing it, or to attack it. The latter is morally better and more healthful. "To act with others as leader or follower; to serve, to coöperate, on occasion to resent or fight, represent normal emotional reactions; to deceive, to act cruelly, to be suspicious, to hold a grudge, represent unhealthful and unsocial emotional attitudes." Fear, worry, and unhappiness of all sorts are harmful, not only because they destroy that social spontaneity and charm which make human adjustments easy, but also because they create divided attention which makes clear thinking and quick decision impossible.

Anger is pathologic in some children, and whether pathologic or not involves the dissipation of an enormous amount of energy. The most important thing in overcoming this tendency is to make the child understand the harm he derives from it. The matter should be talked over with him between his tantrums, as a physician talks over a medical problem with his patient. It helps many children if they are advised to go to the mother or teacher when they feel it coming on. One successful teacher places her hand firmly and kindly on the shoulder of a boy who is enraged; another takes him to the sink and helps him bathe his face in cold water. On rare occasions, children require whipping. When this measure is resorted to, it should never be done in wrath, but after quiet discussion of the matter and for the stated purpose of helping him to remember next time. Ordinarily, punishment administered in this way does not result in sulkiness but rather in sweetness and desire to coöperate in overcoming a harmful tendency.

Love and joy are as essential to normal development as sunlight is to the plant. A little boy of three suffered from an encephalitis following influenza which so injured his brain that he became a low moron in intelligence with a very serious speech defect. His mother was a wise loving woman, but his father was irritated by the child, and nagged constantly. Retarded children are sensitive and very often appreciate their handicaps. It was so in this case. The child, though placed in a school created for the purpose of dealing with such defects, accomplished very little over a period of a year. The following summer his teacher took him to her home, where he was loved and appreciated and wisely handled. In two months he gained 25 points on his intelligence quotient and largely overcame his speech defect. Within one week of his return he began to look worried and to regress, though the mother did everything in her power to compensate for the father's lack of sympathy. There is, on the contrary, such a thing as too much fondling and caressing, both on the part of parents and teachers. This sometimes starts harmful tendencies, especially among older children, and is always emasculating. "Hands off" has many points in its favor.

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* Mental Health for Normal Children, "Mental Hygiene," ii, No. 1.

Of the other emotions, disgust, wonder, positive self feeling or elation, negative self feeling or subjection, admiration, gratitude, scorn, loathing, envy, reproach, anxiety, jealousy, vengeful emotion, and bashfulness, something more should be said about success or elation. Under the illustration of "The Learning Process" (p. 987–8) the ordinary effect of failure has been shown. Unless there is a powerful positive self feeling, failure results in future inefficiency. Where the individual is of the negative type it may result in an inferior personality about which volumes have been written. It is for this type, therefore, that every effort should be made to avoid humiliation. It may be fatal to place such a child in a lower grade. Instead, special help should be given from specially trained and sympathetic teachers. Similarly, it is extremely unfortunate if an older child in a family is outdistanced in school by a younger one. The effort made to keep up under such conditions often results in a low grade neurasthenia from which he never recovers. It would be better to place him in a different school.

Dementia præcox types which are largely the result of emotional maladjustment can be averted in some cases by proper handling if there is coöperation between the parents and teachers. Parents know only in a general way that something is wrong. It is for the school psychiatrist to recognize the real nature of the difficulty, and institute treatment. A boy who had remained four semesters in the 4B grade of the public school entered the Orthogenic School of Rush Medical College. He was extremely nervous and shy, indifferent to all the good times, and unwilling to coöperate in games or work. Everything was tried to secure his interest, and everything failed. Finally, after long consideration, his parents were told that if they could not bring about a different attitude in the boy, he would be whipped. After a little he began to join the other children in their activities at the school, and at the Y.M.C.A., and in a year and a half had reached the proper grade for his age, and was returned to the public school. This boy, however, still needs watching and may have to return to the Orthogenic School to avoid the strain of slow mentality in competition with normal children. His habits also may need further stabilizing. Unless conditions are right, it is just such children as this that go into dementia precox, because failure drives them into the world of fantasy, where they comfort themselves with imaginary success, thus producing dissociation and inability to cope with reality.

Among factors of importance in handling children, whether normal or abnormal, is truthfulness and reliability on the part of the teacher. One of the most difficult children ever handled in the Orthogenic School was a low borderline girl, who refused to apologize for some misdemeanor. She was told that she could not go home until she had made the matter right, and she kept herself and the teacher at the school until six o'clock. Then she said: "You're the funniest teacher I ever saw. When you say anything, you mean it, and you never forget. Miss K—*you never forget!*" If the rest of her contacts in life had been as reliable as this, all of her adjustments would have been comparatively easy.

Volition.—Conflict with the environment, with physical abnormalities, with the disposition, and with tendencies makes attention, conscious reflection, and new methods necessary every step of the way, and in so doing develops habits of coördination and self-control. This ability to control one's self and the situation, so far as it is right to do so, depends upon opportunities for initiative, upon daily training in habits, and upon the environment, which should afford sufficient difficulty to require considerable effort, but not so much difficulty as to permit too frequent failure. As has been said, success is absolutely essential for good development in any line.* If satisfiers and annoyers strike a happy balance in early life, stable reactions will be secured. If the annoyers are too much in the ascendancy, permanent irritability may result with consequent permanent lack of control. Hand work has great value for most children in teaching them not only the right coördinations of body, but of the mind and disposition as well.

Type of Character.—The treatment of the sensitive type has been discussed under "The Imagination" and "Treatment of the Emotions." The active, masterful child should be placed with children of his own or greater strength and ability, and he should not be brought into public notice. If his brothers and sisters are younger or weaker, it is important to develop his sense of responsibility for them—he is to be a protector, not a bully, and much of his work should be made a little difficult. Children of the amorphous type require a steady environment till habits are formed. If the environment is not good, the family should move. This is the most problematic of all types. Nothing but patient persistence in the establishment of early biological habits, and of later mental and moral habits, can overcome the weakness that seems inherent in these children.

Behavior depends upon native equipment, the formation of habits through training, and the environment. Behavioristic difficulties have their origin in early life, often before the age of six. They are closely related to parental incompatibilities, and inefficiencies, and to information and experience acquired through associates, either juvenile or adult. Dr. William Healy has made a genuine contribution to this subject in his book "Mental Conflict and Misconduct." In this he furnishes repeated and almost incontrovertible evidence that frequent impulsions in the form of habitual stealing, lying, cheating, cruelty and truancy are closely related to early sex misinformation or experience. In order to help these children it is necessary to get underneath the surface and bare the real facts. Running away from home and truancy should be handled by the parents, in coöperation with the teacher and physician, first being sure that running away is not due to epilepsy, or to sex complexes, or to complexes concerning parentage, etc. It is sometimes important to run a risk in order to produce the discomfort that is necessary to cure the tendency. The typical runaway enjoys the tears and reproaches of his distraught parents. Let them evince some nonchalance in the matter, let there be considerable discomfort experienced without home and mother, let the innocuous "copper" function properly, and the cure is assured unless, as has been said, there is a hidden conflict. If at home there were a workshop in the cellar or back yard, by which the child could correlate the manual work of the school, and a parent who could teach him to understand the condition into which he has developed, and work with him intelligently to get out of it and, if at school there were a psychiatrist who would assist and guide him in handling the vital problems of his mental and physical energy, hospitals for the insane and institutions that deal with neurasthenics and psychasthenics would find their work steadily diminishing. It is probable that the future will see a great change in this direction.

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* Burnham, W. H., Success and Failure as Conditions of Mental Health. Mental Hygiene, iii (July, 1919), pp. 387–397.

Environment.—The effect of the over-dominating parent is well illustrated and discussed by Milton A. Harrington, "Mental Disorder in Adolescence," Mental Hygiene, iv, No. 2 (Apr., 1920), p. 364; by Elida Evans, "The Problem of Nervous Child;" by W. A. White, "Mechanisms of Character Formation;" and by William Healy, "Mental Conflict and Misconduct." All of these authors not only emphasize the importance of parental guidance and of early training in good habits, but they also insist that development comes as the child learns to choose wisely and thoughtfully for himself and as he acquires the power to carry through that which he has chosen. This implies training in judgment and persistence and a willingness to let the child learn the lessons of life through his own mistakes, if necessary. It implies hours and days and years of faithful, wise watching and silent solicitude and proper action at the right time and only at the right time. It involves time and patience and self sacrifice, but the product is worth all it costs.

Boarders.—Many poor families eke out their income by taking boarders, usually males. This is dangerous: quarters are too crowded for the family privacy which should surround children.*

Poverty per se is not the first cause of delinquency. In early New England where incomes were smaller than among the poor living in the large cities of this generation, delinquency among children was almost unknown. Poverty becomes a menace when it forces families to live where associations are evil and where tenements are overcrowded.

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* Kelly, Florence, "Modern Industry and the Family," Breckenridge, S. B., and Abbott, "The Delinquent Child and the Home."

Church affiliations are usually beneficial. The child needs religion; he has an instinct which leads him naturally to regard a higher Power. Though many regard the child's concept of God as the objectifying of his own highest moral ideal, it will be denied by very few that the personifying of this ideal gives the child a standard of sincerity by which he may measure his moral feeling and behavior. Religious affiliations are also significant because they teach children to pray. What other method has been devised which establishes in so practical a way the habit of spiritual aspiration?

Amusements that involve the child's own effort and activity are those to be encouraged, and for which provision should be made (Plays and Games). Movies and other external and unnatural and moral excitants should be withheld, or at least used with great discretion. So much has been said about the harm that comes to children from movies that nothing is necessary here, but it may be emphasized that the harm is quite as much physical and mental as moral.

Leisure Time.—The serious results that frequently arise as an outcome of idleness after school are recognized quite generally by educators. Some schools continue in session until five o'clock in the afternoon, play or work being supervised so that it partakes of the nature of play under proper conditions (p. 1077). Settlements and other community organizations are valuable in these regards. Churches should provide recreation for after school hours on work days, patterned after the Vacation Bible Schools. Y.M.C.A.'s are already functioning admirably. In rural districts and villages the need is greater. If it is met at all, it is by some enterprising, intelligent mother. Local women's clubs could very well arrange for such directed activities.

Treatment of School Difficulties.—Allusion has already been made to the Binet-Simon tests. As each test requires at least 20 minutes, it is desirable to use the National or the Haggerty intelligence tests* for group examining, following them with the Binet-Simon tests for children known to have difficulty or to be below the average. Tests for sensory and motor deficiencies are given elsewhere and are elaborated in Whipple's Manual of Mental and Physical Tests. Tests for reading, number work, etc., are given under their separate headings.

The headings under "causes of retardation" in the summary were used as items of seeming importance, under which facts could be classified bearing on school progress. They are taken from "Study of a Slow Progress Group with Special Emphasis on the Causes of Their Retardation," Edith Mitchell Ennis, Evanston Public Schools, District 75, and "Study of One Hundred Retarded Fourth Grade Pupils by the Binet Scale," by W. I. Lacy, Northwestern University. Most of the facts except those under *Administration* have already been discussed.

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* World Book Company, 2126 Prairie Ave., Chicago.

In almost all public school systems the classes are at least twice as large as they should be. There are teachers in first and second grades in Chicago who are attempting to handle 52 pupils, eight or nine of which are subnormal. Some way they grind them through so that they are able to pass on into the next grade at the right time, but such methods cannot be in any real sense educative. The responsibility of educating the public to the importance of large appropriations for school purposes rests upon superintendents and other educational leaders. No one, however, is in so good a position to understand the hygienic requirements of school children and the changes necessary for their proper handling as school physicians, and hygienic requirements include proper mental and emotional training and training in habit formation.

Grading is more flexible than formerly. The bright child occasionally skips a grade to great advantage. Brilliant children are sometimes mildly delinquent simply because they have no outlet for their superfluous energy, and if they are pushed to capacity in school, will drop their delinquencies because they become otherwise interested. If the child is very brilliant, the problem is a difficult one, because much more must be considered than the intellect proper. It is an undeniable fact that the boys and girls who are the intellectual leaders of their classes, as a rule, fall behind as leaders in later life. Leadership depends upon initiative, self assurance, and executive ability primarily—qualities not sufficiently considered in school curricula.

The dull child is far better off in special rooms where he can have more individual attention. If this is impossible, it is often an advantage to push him on with the proper grade for his age before he is intellectually ready. There is a positive developmental value that comes from association with those of the same age which demands serious consideration. A certain amount of reading and writing is necessary for all children, and must be acquired by the retarded child if possible, but the great end in view for all is good citizenship, and this will never be attained by fellowship with children three and four years younger.

Some of the most progressive educational psychologists have already undertaken the analysis and reorganization of the common school branches (see Reading, Writing, etc.) and believe that for the immediate future psychology will turn its efforts more largely to the practical uses of the schoolroom. Attention is also being turned definitely to the fundamental habits of behavior. From the kindergarten on through the higher grades, emphasis in school work is laid on habits of initiative, investigation, independence, self-control, punctuality, coöperation; traits which produce efficiency and build character, which hold the child to the steady maintenance of positive goodness for himself and oblige him to loók and work for positive goodness in the social life of his environment.*

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* Proceedings of the Twenty-third Annual Meeting of the International Kindergarten Union (1916), p. 53.

MONTHLY REPORT ORTHOGENIC SCHOOL CHART 10

NAME.. AGE.........

Attendance Regular..... Prompt.....									Interest..............								
Reading Oral.......... Silent..........									Self-control and poise...								
Spelling................									Coöperation..........								
Arithmetic.............									Care and neatness......								
Geography.............									Perseverance..........								
History................									Consideration.........								
Writing................									Honesty...............								
Language..............									Self-reliance..........								
Phonics................									General attitude.......								
Manual training........																	
Cooking and sewing.....									Progress..............								
Hand work.............																	
Rhythm................																	

After the third grade when the child has established considerable power of coördination, awkward and inefficient behavior should be analyzed by the teacher in order that the specific difficulty may be discovered, and a better method substituted. The ease which follows the frequent repetition of acts done properly, resulting in accuracy, rapidity, and freedom from fatigue, is easily demonstrable to children. Furthermore, he may learn relatively early to approach each simple, concrete problem as a unit, and correlate the different steps into a harmonious sequence with the larger view of the problem as a whole in his mind. The importance of such habitual methods of mental and mechanical activity cannot be overestimated as conservers of energy and efficient agents in preparation for life, if they are handled objectively by the teacher so that introspection on the part of the child with its resulting timidity is avoided. Children can be made to see the advantages and feel the power that result from the formation of good habits through practice in games of skill, as in hitting a mark, and it is comparatively easy to use such happy experiences as affective illustrations of what may be gained in more abstract, and less interesting mental processes. There is a great advantage in holding before the child an arbitrary standard, or better yet, a standard reached by deliberate effort on the part of the class, or a good standard already attained by himself.

Awkward coördinations should be recognized as such and deliberately avoided. In other words, indefinite, unintelligent, inattentive, and haphazard procedures should never be allowed while the child is at work.

Psychologic investigation of manual training has had for its object the study of muscular coördination in manual work and has used highly specialized apparatus, *viz.*, the cinematograph and the cyclegraph photograph to discover superfluous, slow, and useless movements on the one hand, and efficient, economical, work-shop movement on the other. These investigations have been carried on by A. A. Douglas and W. T. Dealey* and others. Minimum essentials are also being given considerable attention. Most interesting experiments in spelling have been worked out by Ayres (Russell Sage Foundation). Physical education workers are also endeavoring to establish minimum essentials in their line.

This is of paramount importance in cities of the first class with a large, foreign, laboring population. In communities especially where the foreign element is peasant, Slavish or Italian, or where there is a large number of negroes, the proportion of retardation is so great that minimum essentials only can be acquired. For the exceptionally bright child in these groups, it is unnecessary to say that more advanced opportunities must be afforded.

The matter of the *conservation of school time* is also under consideration: Douglas and Dealey cite school surveys in which it has been found that no small number of school children are wasting 35 minutes daily in unintelligent effort. Mr. C. H. Judd, Director of the School of Education of the University of Chicago, by procuring good habits of study and rearranging the school curriculum so as to discard unnecessary duplication of material, has succeeded in condensing the work of the elementary school into seven years instead of eight, the usual length of time thought necessary to complete an elementary school education. Pupils in the High School of the School of Education who have completed their elementary work in the shorter period seem not to have suffered nervously, though it is perhaps early to secure accurate data in this regard.

School Examinations.—Lewis M. Terman, author of "Measurements of Intelligence," has brought together† the conclusions of three investigators of this phase of school work. Ignatieff watched the effect of examinations upon 242 pupils in a Moscow Military School and found that 79 per cent. of them lost weight during the time, that practically all of them failed to make the normal gain, and that a return to normal in some of them was extremely slow. He compares the physical effect of an examination period to severe illness. Serafani and Koginoff bear him out in similar experiences. The hematological studies of Graziani and Helwig on the effects of protracted mental strain are still more convincing. Tests show that during examination periods there is a 10 per cent. decrease in hemoglobin in university students, and a decrease of 7.4 per cent. in children.

Terman makes a plea, therefore, for the substitution of examinations by brief, interesting, and non-injurious mental tests, stating that the latter are more hygienic and accurate. He says that "the feeling of self distrust and diffidence often engendered by repeated failure is the most constant symptom of that condition of volitional ineffectiveness known as psychasthenia." For this reason he urges the use of Binet tests or some standard modification of them, so that children may be graded according to their mental capacity.

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* Micromotive Studies Applied to Education, Ped. Sem., xxiii (1916), p. 241.

† Fourth I. C. School Hygiene, iii, p. 504.

In a study of psychologic characteristics of the intermediate grades, Mr. C. H. Judd draws attention to a period of relative retardation and difficulty of adjustment already noted in this article (p. 922) which occurs quite uniformly in the fourth grade, and perhaps the early fifth. School failures are more common at this time than at any other. Children retrogress in reading, writing, drawing and arithmetic, seemingly because they are passing beyond the necessity of the drill of the earlier grades and are feeling their way toward a bolder and more self assertive expression. They stumble in their mental coördinations because their interest is shifting from activity for its own sake to the end to be accomplished. Ideas, instead of animal energy, begin to dominate life. Skill, purpose, and quality begin to rise above force and quantity. Even the characteristic diseases of childhood are replaced by the characteristic diseases of adult life. It is a difficult period for teachers and parents to handle, requiring sympathy and a complete understanding of the situation.

COURSES IN MENTAL HYGIENE

W. H. Burnham has recently made a survey of mental hygiene as taught in the various teacher training institutions of the United States. He suggests the following course:

I. Introduction: Scope of the subject references; some examples of emotional states reflected in bodily states.
II. Internal secretions; general nature, illustrations of their influence; organs of—thyroid, thymus, pituitary, pineal, adrenals, gonads, pancreas; hormones and chalones. Cannon, Chapters 1 to 8.
III. The visceral nervous system. Howell.
IV. The central nervous system. Laboratory study of neurones, cross sections of spinal cord, superficial anatomy of brain.
V. Reflexes.
VI. The functions of the brain. Loeb: Instincts; associative memory, localization. Crile: The relation between the physical state of the brain cells and brain functions, p. 111.
VII. A mechanistic view of psychology. Crile, p. 127.
VIII. Phylogenetic associations and the emotions. Crile, p. 55.
IX. The general laws of heredity.
X. Neurosis. Freud.
XI. The teacher and the parent as makers of character. Mental hygiene in the school and home.
XII. The relation between religion and bodily condition.

And finally, it may be said that the great problems of education are the development and control of instincts, the formation of habits and the manipulation of the environment to fit the needs of the growing organism, all working for the production of good citizenship in it's broadest sense. Therefore it is not enough for teachers to receive this education. School physicians, psychiatrists, psychiatric and other social workers, public health nurses, pastors, judges, and all persons connected with Juvenile Courts, the administrators of public affairs, and parents are also responsible and require it.

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FATIGUE

"Fatigue is that diminution in efficiency which rest can cure."* It may be either mental or physical. It is well known† that muscular exercise produces a poison which circulates in the body creating fatigue. Causes of *nervous* fatigue are muscular strain, as in the prolonged use of the eye or neck muscles, and an alteration in resistance to the conduction of nervous impulses at the synapses of neurones, especially of

* Thorndike, E. L., The Curve of Work, The Psychol. Review, xix, No. 3 (May, 1912), p. 180.

† Lee, American Jour. of Physiology, xviii (1907), p. 267.

those in the higher centers.* Such alteration may be induced by muscle fatigue or other toxins, malnutrition, and lack of proper food, unnatural food stimulants, insufficient sleep, tuberculosis, malaria, hookworm, chorea, etc. Causes related to mental activity are such as uninteresting studies or new studies, class periods of too great length, a poor arrangement of class periods, too difficult work for young children, too long a school day, excitement, worry, and failure.

It is necessary to make a distinction between being bored and being fatigued. An experiment in continued work in adding, memorizing, etc., shows that a subject may *feel* more and more fatigued, even though his work, by effect of practice, gets better and better (Thorndike). If work is without interest it creates in the mind of the worker feelings of ennui, repulsion, and perhaps pain, and it probably creates actual resistance to the natural flow of energy by the effect of chemical irritation of fatigue products at the synapses.

Symptoms of Fatigue.—The subjective symptoms are:

1. Local sensations of fatigue especially in muscle (protective in function).
2. A feeling of general tiredness or limpness, and general incapacity for effort.
3. Sleepiness.

Physical symptoms of fatigue are anorexia, poor assimilation, loss of weight and anemia. Some experimenters have thought that the distance at which two simultaneous touches on a given circumscribed area of skin could be distinguished as two touches was a measure of fatigue, but these experiments have not been carefully made† and are not trustworthy. Tests of fatigue are described by Offner and Whipple, "Mental Fatigue." They are memory tests, or tests of attention, applied at different times of day. A feeling of fatigue manifests itself more at the beginning and toward the end of work. It is difficult to overcome natural inertia and rouse energy for the effort of a different kind of work, especially if the previous work has been of an interesting nature. Practice and habituation reduce fatigue materially. Children have more difficulty, and it takes them longer to make new adjustments to work, than adults. There is a great difference in the nature of school subjects; mathematics, sight translation, etc., producing a feeling of fatigue quicker than the less formal branches. The absolutely indispensable factor of education —attention—depends upon interest. Abstract subjects like the above can be made less fatiguing if they are accompanied by external incentives, or if the child's rating is charted from day to day so that he has the internal stimulus of self-satisfaction. If work is planned also in such a manner that the relation of the present material to that which has been studied before can be seen, interest and attention are secured with much less difficulty. This is a very important point. Objective material is another source of interest,* as it makes attention easy, reducing the sense of fatigue.

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* McDougall, W., The Conditions of Fatigue in the Nervous System, Brain, (1909); Sherrington, "The Integrative Action of the Nervous System," p. 214, etc.

† Thorndike, E. L., Psychological Review, vii, pp. 466 and 547.

Treatment.—School work hardly ever produces real fatigue, so that it is ordinarily safe to insist upon pursuit of work even though the pupil complains. Children's minds must be inured to difficulties and trained to persistency. Only in this way are those "vital reserves" stored and the will developed that makes it possible for the adult to surmount the great difficulties that face him later. However, as there will be work enough to do at best any intelligent method of procedure is legitimate that reduces the volume of work or the unessentials, or that creates efficient habits of mind, thus reducing the total output of work during life. It is said that when the mind works automatically it works economically; therefore, the multiplication table, spelling, the parsing of verbs, etc., should be learned "by heart" and without trying to reason.†

There is a point beyond which fatigue should not go, because it may become permanent. If it is found that the child is becoming irritable, too emotional, over-anxious, self-centered, afraid of failure, undecided, or sleepless, or if he is not gaining weight properly, his work should be reduced, or the environment entirely changed. While the will counteracts fatigue, and puts at our disposal existing energy lying dormant, it nevertheless reduces that energy at the same time, so that nervous children must be guarded from too much continuous effort.

Fatigue appears after an hour of work in six-year-old children. Therefore, there should be great freedom in school activity among young children. From this time on fatigue appears increasingly less until the period of puberty, when it again reasserts itself. Short periods are best for young children, and except for periods of free play learning should be mechanical; no period for this age ought to last longer than 15 or 20 minutes, and two minutes should suffice for drill in number work. Longer periods are necessary where a train of thought is to be developed, as in geography, and older pupils may spend 45 minutes in consecutive mental work with ease. The school program requires such planning that there shall be the proper amount of work, rest, recreation, exercise, and food. The more difficult subjects should be taught after 10 o'clock in the morning, as the first hour is required for "warming up." The same holds true of the afternoon, though on the whole afternoon hours are less satisfactory than morning hours. After Wednesday also efficiency decreases, so that subjects presenting special difficulties will be mastered better if emphasized Tuesday and Wednesday, when practical. Individual teaching is far more exhausting than class work, and if it is to be helpful must be reinforced by longer periods for rest and the organization of association processes. An interval of 5 or 10 minutes between recitation or study hours is important and there should be a 15-minute recess period morning and afternoon; two days at week ends, or Wednesday instead of Saturday. Vacations should occur at Christmas, at Easter time or a little later, and during the summer. The long vacation lasts nine weeks ordinarily, and the others one or two weeks.

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* Freeman, F. N., "How Children Learn."

† Colvin, "The Learning Process."

Social activities are good if they are not too exciting and if they do not absorb the attention.

Gymnastic activities are better if not too vigorous unless they precede food and rest. Four minutes of light calisthenics are excellent between class periods, and it is very advantageous for children to pass from one room to another for class work.

In 1910 the Prussian Minister of Education issued a law making periods of rest compulsory on account of the great numbers of suicides among high school students. This manifestation of overstrain had assumed such disastrous proportions that a committee was formed to investigate the matter. The conclusion reached by them was that too long hours of school work, too much work at home, and too little sleep were chiefly responsible.*

The Federal Government of the United States has recognized the importance of fatigue in relation to the physical development of youth, and has instituted standards for the control of child labor.

The following are the minimum standards for child labor for children in the United States:

"*Age Minimum.*—An age minimum of 16 for employment in any occupation, except that children between 14 and 16 may be employed in agriculture and domestic service during vacation periods until schools are continuous throughout the year.

"An age minimum of 18 for employment in and about mines and quarries.

"An age minimum of 21 of girls employed as messengers for telegraph and messenger companies.

"An age limit of 21 for employment in the special delivery service of the United States Post Office Department.

"Prohibition of the employment of minors in dangerous, unhealthy, or hazardous occupations, or at any work which will retard their proper physical or moral development.

"*Educational Minimum.*—All children between 7 and 16 years of age shall be required to attend school for at least nine months each year.

"Children between 16 and 18 years of age who have completed the eighth grade but not the high school, and are legally and regularly employed, shall be required to attend day continuation schools at least eight hours a week.

"Children between 16 and 18 years of age who have not completed the eighth grade, or children who have completed the eighth grade and are not regularly employed, shall attend full-time school. Occupational training especially adapted to their needs shall be provided for those children who are unable, because of mental subnormality, to profit by ordinary school instruction.

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* Kruse und Selter, "Gesundheits pflege des Kindes."

"Vacation schools placing special emphasis on healthful play and leisure time activities shall be provided for all children.

"*Physical Minimum.*—A child shall not be allowed to go to work until he has had a physical examination by a public school physician or other medical officer especially appointed for that purpose by the agency charged with the enforcement of the law, and has been found to be of normal development for a child of his age, and physically fit for the work at which he is to be employed.

"There shall be an annual physical examination of all working children who are under 18 years of age.

"*Hours of Employment.*—No minor shall be employed more than 8 hours a day. The maximum working day for children between 16 and 18 shall be shorter than the legal working day for adults.

"The hours spent at continuation schools by children under 18 years of age shall be counted as part of the working day.

"Night work for minors shall be prohibited between 6 p.m. and 7 a.m.

"*Minimum Wage.*—Minors at work shall be paid at a rate of wages which for full-time work shall yield not less than the minimum essential for the "necessary cost of proper living," as determined by a minimum wage commission, or other similar official board. During a period of learning they may be rated as learners and paid accordingly. The length of the learning period should be fixed by such commission or other similar official board on educational principles only.

"*Placement and Employment Supervision.*—There shall be a central agency which shall deal with all juvenile employment problems. Adequate provision shall be made for advising children when they leave school of the employment opportunities open to them, for assisting them in finding suitable work, and providing for them such supervision as may be needed during the first few years of their employment. All agencies working toward these ends shall be coördinated through the central agency."

These standards have not been adopted by all the states, some of the southern states having no restrictions upon child labor.

SLEEP

Metabolism, growth, and activity are greatly increased in children and there is far less stability of the nervous system. During sleep the output of carbon dioxide is reduced to one-fifth, and oxygen is stored. Moreover, sleep not only gives chemical rest but mechanical rest as well. Most of the growth in height occurs in bed. Children who do not sleep are stunted in physical development and are anemic and poorly nourished; they have poor power of attention and of memory, and there is not enough time for their association processes to organize the material which has been presented to the mind during the day.

Dr. Lewis M. Terman* examined 2,692 children to ascertain whether social status of the home, home study, and the possession of typical nervous traits had any relation to the hours of sleep, or if the latter bore any relation to school success. He found that there was no correlation either above or below, and that no one point seemed to be in any way related to the other.

Bernhard, of Germany, and Ravenhill, of England,† found that there was a deficiency of sleep amounting to nearly 25 per cent. in school children. Nearly all physicians emphasize the need of sleep for the growing organism. Sherrington states that boys between 13 and 15 years of age require 10 hours of sleep, and further that they should retire at 9 o'clock and should not be disturbed by people coming in, as the quality of sleep is as important as the quantity.

Duke's table is as follows:‡

TABLE 34

AGE	HOURS	AGE	HOURS
Under 6	13	Under 10	11
Under 7	12½	Under 13	10½
Under 8	12	Under 15	10
Under 9	11½	Under 17	9½

TEACHING OF HYGIENE

The last few years show a notable advance in the interest manifested by school children in matters pertaining to personal, family, school and public health. Revelations of physical defect in the population of North America during the recent war demonstrate the necessity of educating children in health habits, in the correction of physical defects, and in a knowledge of the facts, principles and motives which underlie or influence the production of health. Work of this character cannot be regarded as effective unless it is made sufficiently vital to carry over into the outside every day reactions of life. In fact, this is practically the only purpose of teaching school hygiene. Many educators believe that unless greater emphasis is placed on social or community hygiene, children will not be interested in the subject; in other words, that to make the matter of moment to the child, factors less directly centered upon himself must be brought to the foreground. Undoubtedly too much has been said in the past, at least to younger children, about physiology, anatomy, bacteriology, etc., which rightfully belong to the High School curriculum, and too little about the actual, practical experiences of health. Wood, Reesor and Bonser have published an article entitled "Health Instruction in the Elementary School"§ illustrating the method of teaching hygiene in connection with the child's daily experiences in the home, school or community, or as related to other phases of science which are being studied in school.

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* The Sleep of School Children: Its Distribution According to Age and Its Relation to Physical and Mental Efficiency, Fourth International Congress of School Hygiene, iv, p. 38.

† Both quoted by Terman.

‡ Warner, "Study of Children."

§ Teachers' College Record (May, 1912).

The Speyer School* presents the following method of teaching hygiene: Hygiene of the home is taught by games representing the mother's activity in getting children ready for school, the child's duties to his person, the preparation of breakfast and simple care of food, the airing of beds, sleeping and ventilation. At the lunch period the use of napkins is taught. During daily work there is constant training in personal habits (turning of the head when coughing, the use of handkerchiefs, pencils, drinking cups, etc.).

First Grade.—A miniature flat is constructed, and the children are taught the care of the house and the care of pets and animals.

Second Grade.—Nature study. This phase of work is presented by Jack Frost and his playthings (water used in cooking and growing, ice, snow, etc.), buds, seeds, plants, germination, home pets; the cats, food, clothing, teeth, feet, tongue, whiskers, etc., the care of the cat; clean habits.

Third Grade.—Homes; their lighting, heating and ventilation. The modern home is compared with the Eskimo, Indian, Cliff dweller, Hebrew, American, country cousin, city cousin. The care of stables for cows is studied and also the care of milk and refrigeration. Further topics are dust, rubbish, etc.

Fourth Grade.—Climate, clothing and food are taught through interest in geography and industrial activities. The principles of lighting and plumbing are also included in this grade.

Fifth Grade.—The topics are school life and service; school sites, school lighting, heating, temperature, ventilation, furnishing, toilets, water fountains, drinking cups, paper towels and soap, disinfectants, fire protection; janitor and helpers; street cleaning department, police department, fire department, how the city cares for and protects its schools, Departments of Health, sanitary codes, etc.

Sixth Grade.—This grade includes race studies, industries and factory life, tenement houses, water supply, hospitals, dispensaries, parks and playgrounds, pure food laws, vaccination, tuberculosis, and modern conditions.

Seventh Grade.—The school class is organized into a Civic League, for community, school and civic improvement. Monthly reports of investigations are made and work is actually accomplished. Some problems are referred to the League by the lower grades. Children of the seventh grade also study the nature of soil, drainage, climate, natural conditions, rivers and sluggish water. Health laws are investigated and the civic powers involved in the municipal government of New York City (any city).

Eighth Grade.—Here the pupils are taught the responsibility of citizens in electing good officers, the facts regarding epidemics, immigration, prevention of tuberculosis, temperature, effect of tobacco, accidents and drowning, methods of preventing and dealing with fire, and the more salient features in bad buildings. Industrial diseases, bad habits, etc., are also under consideration.

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* *Ibid.*

Some educators would feel that topics rightfully belonging to civics have been introduced here. If so, the point of view can be altered so as to make health topics secondary to civics, but the connection should in some way be maintained.

The New Jersey system includes a study of the special sense organs, exercise, sleep and rest, the alimentary tract, circulation, respiration, the nervous system, drugs, accidents and emergencies, self-control and good manners.

The following is an outline of the course given by the Department of Public Instruction, Trenton, New Jersey, the title of which is "The Teaching of Hygiene and Safety;"

I. Personal hygiene.
  (*a*) Health of the body and bodily action.
  (*b*) Health of the mind and mental action.
  (*c*) Proper social relations and moral conduct.
II. Family hygiene.
III. School hygiene.
IV. Community hygiene.
V. State hygiene.
VI. National hygiene.

In each of these fields three phases may be recognized:

1. Conservation or preservation of health.
2. Improving health and health conditions.
3. Eradicating disease and removing disease-producing conditions.

No matter what method is used the teacher's inspection of children should precede the morning exercises of the kindergarten, and continue through school. Instruction in hygiene naturally occurs with the inspection and centers about cleanliness of the hands, clothing, shoes, etc.

Opinions differ as to the advantages of beginning health instruction below sixth grade. In the School of Education of the University of Chicago no formal instruction of this kind is prescribed in the earlier grades, but the clientele of this school is composed of families of intelligence, who attend to the health habits of their children. In public schools with a mixed and often unintelligent clientele it is very essential to begin at the outset to drill children in the care of their teeth, in cleanliness, etc. If hygiene is taught all through the grades, at least 30 minutes a week should be devoted to it. If it is taught in one grade, it should occupy 30 minutes daily during the six months devoted to it.

The Department of Education of the City of Boston "Provisional Course of Study in Physiology and Hygiene for the Elementary Schools"* presents excellent material. Kansas, Virginia, Minnesota,

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* School Document No. 6 (1910).

New York City distribute printed health educational matter both for parents and children. Virginia publishes a Health Bulletin covering such topics as First Aid, Prevention of Accidents, Public Health Catechism on Preventable Diseases, Malaria, etc. The Department of Health of New York City publishes monthly health bulletins for school children called "School Health News" discussing such topics as Headaches, Hands as Transmitters of Disease, Dangerous Appetites, etc. An excellent outline, not printed, on Teaching the Care of the Baby is in use by the Department of Health of Chicago.

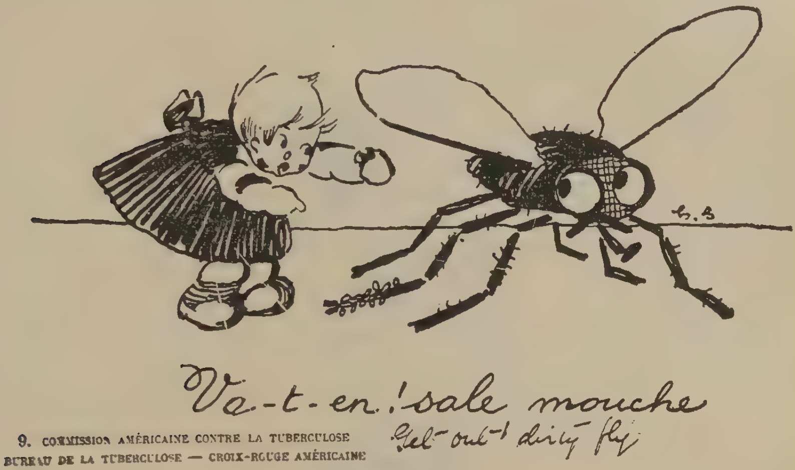
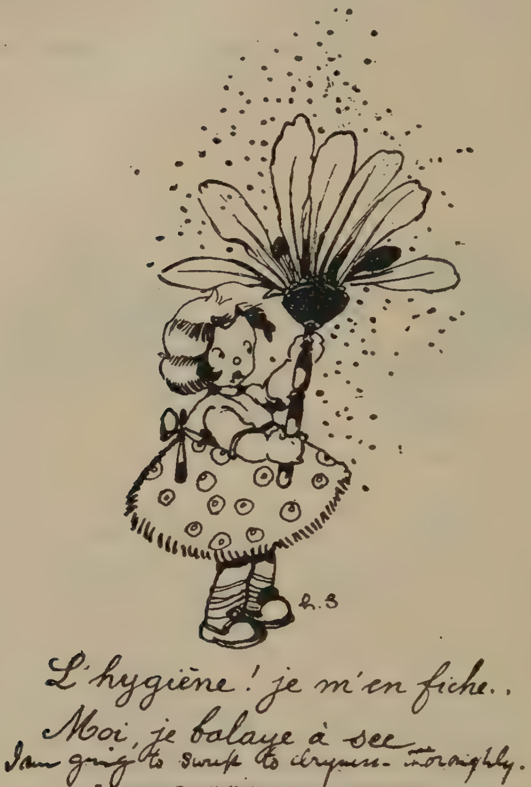

Va-t-en! sale mouche
Get out! dirty fly
9. COMMISSION AMÉRICAINE CONTRE LA TUBERCULOSE
BUREAU DE LA TUBERCULOSE — CROIX-ROUGE AMÉRICAINE

FIG. 250.—A French method of teaching hygiene to children.

There are many stimulating adjuncts to the teaching of hygiene: graphic material in the form of models can be procured from the Educational Equipment Company, 70 Fifth Ave., New York City. Hygiene charts may also be procured from this firm. Dr. Thomas D. Wood (of Teachers' College, New York City) has published a pamphlet on Health Charts which contains illustrations of something over 50 charts covering phases of health, interesting to children and to parents. The Educational Museum of Clark University (Worcester, Mass.) presents a very fine Catalogue of the Department of School Hygiene, containing an exhaustive description of suggestive and graphic material. Children may make charts themselves by assembling pictures which are pertinent to the subject or by drawing illustrative pictures. These interest them much more than any charts that can be bought.

Such work is discussed in a pamphlet entitled "Teaching Health" published by the Department of the Interior, Bureau of Education, 1919. Other suggestions will be found in the Fourth International Congress of School Hygiene, iii, p. 48. The French use rather grotesque posters (Figs. 250, 251) which are both instructive and amusing to children. Many museums offer some of their movable material to schools* and much can be done through Child Welfare Exhibits.† The Bureau of Welfare of School Children in New York City, the Elizabeth McCormick Fund of Chicago, and some Life Insurance organizations publish very helpful material.


R.S
L'hygiène! je m'en fiche..
Moi, je balaye à sec
I am going to sweep to dryness thoroughly.

7. COMMISSION AMÉRICAINE CONTRE LA TUBERCULOSE
BUREAU DE LA TUBERCULOSE — CROIX-ROUGE AMÉRICAINE

FIG. 251.—A French method of teaching hygiene to children.

Health can be taught dramatically with excellent results, as in other lines of education. This phase of the subject is presented very ably by F. M. Gregg.‡ The nurse, and her place as a teacher of hygiene, and her methods of doing it, are discussed in an article full of suggestions by Katherine Olmstead.§ There should be at all times the closest coöperation with the Department of Health, the Tenement Department, the Fire Department, and the Street Cleaning Department.*

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* Winslow, C. E. A., Museum Coöperation in the Teaching of School Hygiene and Sanitation, F. I. C. S. H., iii.

† Powlinson, C. F., The Influence of Child Welfare Exhibits on the Health of School Children, *ibid.*

‡ Teaching Hygiene as Nature Study, F. I. C. S. H., iii, p. 266.

§ Effective Methods of Teaching Hygiene in Schools, American School Hygiene Association, vii, p. 29.

The most remarkable impetus to the practice of hygiene has recently come to school children from several sources. Dr. Emerson's work in nutrition (p. 928), Dr. Fones' work in dental hygiene (p. 954), Miss Jessie Bancroft's work in posture (p. 966), the agitation about flies, and the methods of reward for their extermination, have all produced excellent results. The nutritional chart which visualizes the child's effort and success, or failure, by means of a chart which all may see, the impetus of room rivalry given by some live teachers to older pupils in regard to both their own teeth and those of their neighbors, is most interesting. The younger pupils of a High School of Chicago, having had their own dental defects corrected, assumed the responsibility of a public campaign of the neighborhood teeth, and made a survey by means of a house-to-house visitation. Much depends, of course, upon the personality of the teacher, and her preparation for such work. She should be an inspiration, but such inspirations often require a tempering quality which not only enthuses but restrains the ardor of youth in public endeavor.

Colleges and normal schools have been very slow in seeing their opportunities and responsibilities in this phase of education, but courses in personal and school hygiene are now being more generally organized throughout the country.

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* Goldwasser, I. E., Pupil Coöperation Indispensable in Enforcing Hygienic Regulations, F. I. C. S. H., iii, p. 163; Hunter, G. W., An Experiment in Student Control of School Sanitation and Hygiene, *ibid.*, p. 283.

Value of Exercise and Rest to Public Health.
Values of Pure Foods and the Physiology of Digestion.
The Cause and Prevention of Nervous Prostration.
The Prevention and Cure of Tuberculosis.

The Teaching of Sex Hygiene

There are several conditions met in childhood which make the teaching of sex hygiene imperative, *viz.*, sex abuse, sex misinformation, conflict and delinquency.

Sex abuse which is minor in point of importance presents two facts for consideration:

First: It is almost universal among boys and seems to produce relatively little effect upon them unless they are abnormal. Second: It should be corrected and overcome by reasonable information and the establishment of hygienic habits but it should not be so emphasized as to produce the psychasthenic condition resulting from fear, which is sometimes far worse than the habit itself The symptoms of masturbation are friction, day dreaming, auto-erotism, mental apathy or irritability, lack of attention and consequent loss of memory and anemia from loss of sleep. There should be no confusion in the minds of boys in regard to seminal emissions. It is necessary to teach them that this is normal functioning. For further particulars see Moll, "The Sexual Life of the Child."

Sex Misinformation.—Except in a few unusually guarded communities, sex misinformation among boys is practically universal before the age of 10. Unmistakable facts have been discovered in boys' schools of excellent reputation, in all the grades of public and private schools and in communities of high standing, showing not only that information of this character is general, but that perverted sex practices among children are very common.

Conflict.—It is a fact that in monogamous countries, largely Jewish and Christian, where the family is stressed as the unit of civilization, the public conscience eventually reaches a stage of social development which is dominated to a considerable degree by the instinct of race preservation. It seems to recognize the fact that among other things the purposeless and sometimes the purposeful discussion of sex leads to thought and occasionally to conduct which it is trying on the above ground to avoid. This probably accounts in some measure at least for the almost universal tendency of adults to avoid the topic of sex, especially in the presence of children. Though this is unexpressed, it amounts to a very strong body of public opinion which, while children do not understand, they feel definitely. Conscience represents the individual's tendencies to do right and is summoned into action when tendencies appear which are wrong. Conflict arises either with a failure to understand or when two instincts mutually antagonistic are aroused. This is well illustrated by the sex instinct which fights for supremacy against the regulative instincts, *i.e.*, the desire to conform to law and to regard a higher Power. If the child does not understand why the sex tendency holds within itself elements of evil and if those to whom he ordinarily looks for help turn away from the subject in a peculiar and mystifying way, so that the energy which accompanies curiosity is repressed and can find no outlet, confusion results first, sometimes followed later by mental conflict which is the result of confusion and repression. If, as is usually the case, some powerful emotional element accompanies the repressed experience, there results a *complex* perpetuated by the vividness of associations which rapidly become systematized into new and dangerous habits of thought. In proportion to the development of conscience the memory of experiences of this type are repugnant, consequently they are buried in the subconscious as rapidly as possible and are often unrecognized by the person who suffers from them.*

There are many social conditions that tend toward the moral disintegration of sex consciousness. Among them are over room congestion, lack of personal privacy, the intermingling of adults and children under conditions and at times which are contrary to the traditions of civilized communities. Further, there are public dance halls, and boat excursions, many of the movies, and until recently the saloon: all contributing significantly to the general trend downward.

Sex Delinquency.—A study——of the causes of recidivism in 2000 juvenile delinquents† —indicates that in 7 per cent. stealing, lying, truancy, sex delinquency, cruelty, etc., have developed into permanent tendencies and that as a general thing they have arisen as the result of early sex traumata.

Dr. Healy gives a detailed list of 40 cases which show that seven of these children were only six years of age and 21 under the age of 10 when they were subjected to the sex information or experience which produced the trauma which made them repeaters in crime. The immediate informants were either older boys or girls. The imagery, which in most cases was strong enough to amount to an obsession, was either visual or auditory and had its immediate genesis in conversation, pictures, drunken orgies, or vice not due to alcohol. The results were those already mentioned: stealing, pathological lying, sex delinquency, truancy, spells of obstinacy, murder, violent temper, and suicide. It is probable, though this has not been proven, that a similar study of ordinary school children whose behavior is particularly troublesome but who are not sufficiently delinquent to get into the courts would reveal a percentage as large.

The following is a study somewhat in detail of a little pupil in the Orthogenic School of Rush Medical College whose mentality and adaptability were seriously injured by mental conflict. The purpose of presenting it is to show the situation in which such conditions frequently arise, the background necessary to establish a cure and the remedial measures employed. It was related by a psychologist connected with the school. As the boy's mother was an honest thoughtful woman, anxious about the welfare of her children, and as it was customary to obtain all the history possible from the parents, she was asked to come to the psychologist's office for an interview. The child was very much under weight and height. The mother was therefore approached on the basis of feeding; it being suggested that she give her boy one quart of milk daily. She seemed anxious to help him but said it was very hard with so many to feed and so difficult for her husband to find work. When it was suggested that she apply to the "Charities" or that the office would apply for her, she said that she had never accepted help and she never would, though she starved. She was then approached upon the subject of bad boys in her neighborhood, whereupon she said she and her husband had decided to move to a less populated district on that account. When asked if Max had learned anything bad from the boys she stated that Max was as pure as an angel of God. This she thoroughly believed. Max had been in the school above referred to for a year and a half and had made very slow progress. Not only was he physically undeveloped but he was very anemic and restless, had a violent temper and sometimes it seemed as if he were in torture. His basal metabolism had been taken at the clinic and found to be 81+. The latter factor, if a manifestation of Graves' disease, may have functioned as a cause. On the other hand, it may have been an effect of his sex tendencies. As a result of observation, he underwent a minor operation in the hospital from which he was discharged as quickly as possible because he upset the ward by his extraordinarily restless and uncontrollable behavior. Shortly after the opening of the school year the psychologist relates that she visited the school one day and noticed that Max looked much better. On a later visit, however, the teacher said "Max is doing poorly. Something is the matter." The psychologist at once turned to the boy and said, "I'm going back to the clinic now, will you go with me?" On the way over some questions were asked as indirectly as possible about the boys with whom he played at home. "Oh yes! They were awful bad. Stole and did things like that, etc." "Do they ever say bad things?" "Yes, terrible things." "Do they ever show you bad pictures?" "Yes." "Do you ever see bad things?" Then followed a recitation of some evil practices occurring in the alley which he said happened frequently. "Do these things trouble your mind, Max?" "Yes, I try and try but I can't get them out." "But do you have to play with these boys?" she questioned. "There's nothing else to do," the boy replied. "Can't you play in the backyard?" "No, the landlord's too stingy. He won't let anybody in there and I haven't any toys to play with in the house. If I had some tools I could make things." As a means of securing his confidence therefore, he was promised some tools and sent back to the school and the case was reported at once to the Juvenile Protective Association for investigation of neighborhood conditions. When Max returned to the school he said to the teacher, "I had a good time, but I was awful scared to go. I thought she took me over so I'd get a needle stuck into me (he had previously had a Wassermann), instead I came back with a pleasant secret." This was the beginning of a series of interviews which, he was told at the outset, were to help him recall everything that was troubling him because if he could do so and he would talk them out, they would go away. Image after image was revived in detail often with great embarrassment. With the revival of each evil image there was an effort on the part of the psychologist to effect a *transmutation by substituting* ideas and images which in the child's mind would stand for reverence, ethical value and true sexual purpose. Max is a sample, not only of the alley child, but insofar as mental conflict is concerned of many nursery children who appear as innocent to their mothers as Max did to his. Dr. Healy says that there is ample proof that these children are not necessarily neurotic, nor the inheritors of neuroses; that as a group they have no peculiar qualities of character, temperament or disposition; that they are not mentally defective, that they have no primary lack of general mental control and no primary inadequacy or disturbances of the processes of mind such as memory, association, imagination, etc. Almost all children are exposed to the evil attitudes, thoughts, words or experiences of older people or sophisticated children. Ordinarily sex impressions of all kinds join the multitude of other experiences in the general melting pot of the mind and cause very little trouble, unless their number is overwhelming; occasionally, however, they strike a highly impressionable, conscientious, imaginative, sensitive child. It is this group, probably, which constitutes the seven per cent. of juvenile delinquents, a larger proportion of psychopathic and inferior personalities, many of the major hysterias, some of the psychasthenias and a considerable number of people living without apparent cause, on a level inferior to their native ability.

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* Freud, S., "The Interpretation of Dreams." "Studies in Hysteria." Nervous and Mental Diseases, Monograph Series, No. 4.

† Healy, William, "Mental Conflict and Misconduct."

Conflicts and complexes of this nature consume mental and physical energy which is beyond all estimate. They injure the disposition and destroy habits of concentration. Memory then becomes affected and the keen edge is taken from all mental activity. Sometimes moral strength comes out of the conflict, but more often a conditioned reflex is established or the child is sensitized (to borrow bacteriological phraseology) so that he emerges from the struggle with a peculiar susceptibility that decreases his resistance. These court children are dominated by compulsions which are too powerful to be resisted. One of two evils is imperative and stealing seems radically better to the child than evil sex thoughts or practices. Because their inner conflict is a sealed book to the majority of adults who deal with them, they are harassed or hardened by misunderstanding. The successful psychologist, be he man or woman, is therefore primarily a friend, who handles the problem objectively but with an element of true motherliness which supplies him with an inspiration he can safely imitate, helps him to unburden his difficulties and gives him courage for sustained moral effort.

The Teaching of Sex Hygiene.—The purpose of teaching Sex

Hygiene should be essentially constructive and may be considered under the following headings:

To establish right root ideas.

To assist in establishing normal, strong habits of thought, concentration, control of the imagination, etc.

To make sex characteristics clear to youth.

To aid in the control of emotion.

To establish early habits of general control and judicious sex standards and to fortify the will against temptation.

To create character and respect for chastity, for normal parenthood, for persistent and loyal family relationships and for social integrity in the community.

To correct misinformation.

To overcome conditioned reflexes.

To prevent mental complexes.

Sex education begins ideally in response to questions which children ask regarding the subject. Exceptionally intelligent mothers, who are skillful enough to present information indirectly so that it will come about naturally, need not wait for questions. They may forestall the child's curiosity by information which is given incidentally in the ordinary routine of domestic life. The preparation of fowls for the table gives mothers an excellent opportunity to use material at hand for lessons in anatomy, showing the heart, crop, intestines, sex organs and unlaid eggs. By presenting all of the organs under exactly the same conditions they establish the right attitude and the beginnings of a proper vocabulary. Other opportunities arise as they teach the care of the genitalia at the time of bathing or when the child is being undressed for bed. The bed time story can be used to great advantage. Stories of father and mother birds and of the little birds provide mothers with means for instruction in human maternity, the more intelligent mothers including instruction in human paternity. Mothers who use these methods invariably testify to the child's candor and freedom from self-consciousness if they have had the first opportunity. It is important to remember that sometimes children do not ask questions because they have had preceding misleading information. If sensual ideas are already installed the child's confidence must first be secured. This done, clear, satisfactory statements of the truth should follow. These statements must be free from sentimental symbolism—not mixed with metaphors whose sole purpose is to cover the embarrassment of the adult who is giving the information.

Too little has been said about the importance of freedom from repression in the family in the discussion of sex matters. Any child, either boy or girl, should feel free to approach either father or mother with questions or observations of this nature. If fathers discuss these topics only with their boys, and mothers only with their girls, an atmosphere of repression and self consciousness is created and this atmosphere does harm. On the other hand, children may safely be taught reticence in regard to sex topics together with the mention of body functions in general. American parents who are prepared by tradition or training to teach their children are very few, therefore parent-teacher associations, and other similar organizations, should undertake parental training. In many communities the school physician is the logical leader of movements like this and perhaps the only one who can give to parents the information which they in turn should give their children. Helpful suggestions for such teaching in the home and in school are found in the bibliography at the close of this article.

Emphasis should be placed not only on the teaching of sex facts but on the importance of coöperative obedience. While positive attitudes and behavior are fundamental, the child must also learn to inhibit, learn it early, and from day to day. This does not mean that he should be constantly or even frequently repressed in moral, mental or physical activity or in the ordinary rough and tumble reactions natural to healthy boys and girls, as these are important for development. It is certain, moreover, that he should not be nagged as nagging checks development, but reasonable consideration for others and self-control are necessary for easy adaptation in the future and if not learned early will be learned at great expense later on. Those who fail in adaptation continually fall into the groups of inferior and psychopathic personalities and are the despair of courts, social workers and physicians. They are the ones for whom there is no place either in the world at large or in institutions because they are dangerous in the former and misfits in the latter. It is of the utmost importance, therefore, that self-control be developed so as to lay the foundations for sex control at puberty when anti-social tendencies ordinarily begin to develop.

The teaching of sex hygiene in school properly begins as *group work*, in the kindergarten or first grade, in connection with plants or with breeding birds and animals, especially ring-doves, guinea pigs and rabbits, which are introduced into the class-room for the purpose of familiarizing the children with the more universal idea of parenthood.

Miss Elsie Wygant, of the School of Education, University of Chicago, furnishes the following experiment in teaching reproduction to the children. "This is the statement of reproduction which the second grade group made. For two consecutive days we had talked this over. I brought in a tulip, daffodil and lily to show them larger pistils in which they could see the process better. The third day, from this explanation and discussion they formulated the enclosed. I have underlined the only help I gave.

'Dear Friend:

I am sending you some pussy willows, gray-green and yellow. I will tell you about them. The gray pussies are the tree's flower buds. When they burst, they turn green. When they are fully in blossom, they turn yellow. The yellow is the pollen. The pollen falls through a hole in the pistil, and makes the seeds.' (I suggested this to get the thing into more general form. They caught the idea as you can see by the following sentence:)

'*Every flower in the world has a pistil and pollen.* Every seed in the world is made by the pollen falling onto a pistil. Sometimes the pollen and the pistil are in the same flower. Sometimes they are in different flowers. A pussy willow tree has pollen flowers on one tree and the pistil flowers on another tree. The wind blows the pollen from one tree to the other. Later we find the seeds on the* pistillate tree. Then these seeds blow away to plant other pussy willow trees.'"

Kindergarten and primary teachers are sometimes appalled by the knowledge and attitude of children of excellent birth and good breeding which is incidentally disclosed. Children overheard discussing among themselves the problems that arise from material which to the mind of a sensitized child may seem suggestible, require careful instruction not in groups but as individuals. The teacher should be sure that she has been able to clear away all debris of an evil nature, as it is her function not only to impart scientific data but to create attitudes of reverence and purity.

The very highest type of personality should be trained for this kind of scientific teaching. Teachers of sex hygiene require a thorough preparation in general science not only to give them the facts but also to fit them to appreciate the unity and nobility of nature in all her phases. It is especially important that children and young people should both like and respect these teachers of sex hygiene because personal influence is needed to carry over the right point of view.

An excellent book for grade work is "Plant and Animal Children and How They Grow," by Ellen Torelle. It may be said incidentally that it is dangerous to place books of this nature in the hands of children, but *instruction should come entirely from the teacher and laboratory material below the high school.* Some very remarkable chapters have been written on sex in plants, notably "The Text Book of Botany," by Strasburger, Noll, Schenck and Karsten, and another of the same name by Coulter, Barnes and Cowles. Others of great value will be found in the bibliography appended. Miss Jessie Phelps, of the State Normal College at Ypsilanti, gives an elaborate and practical course in sex as part of natural science. Dr. Mary Blount, of Chicago Normal College, emphasizes in her courses the fact that children are primarily interested in the sex facts of mammals. The possibilities of natural, wholesome class attitudes in connection with sex physiology are demonstrated in the following incident: A boy in one of her classes, who had been absent during a previous demonstration, asked if he might dissect a rat and work out the problem he had missed. No sooner had he opened the body of the rat than he said, "Why there are a lot of little rats here." Those at the table leaned over and looked at the rat in his tray, and after they had seen it, he said, "Don't some of the others want to see this?" The next day the teacher took advantage of this opportunity and presented the matter in a formal class period.

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* "They had several phrases for the tree 'that the pistil is on,' etc., which were clumsy. After some work on their part I said, 'we call that tree the pistillate tree. Would that help you?' John F. said, 'Yes, why didn't you say that a long time ago; then one word says it all.'"

Full information regarding maternity and reproduction is not enough to satisfy youth—*the aim should be to make them understand themselves.* What is the significance in adolescence of the newly developed energy, idealism and attraction to the opposite sex? What significance has affection, marriage, the family? What is eugenics? What are their social responsibilities?

The teacher may not be able to reach individual difficulties either inside or outside of the class room. Doubtless the most essential thing after all is some sympathetic older person of intelligence and experience, pastor, priest, physician, psychologist, parent, dean of girls, teacher or friend who will encourage the perplexed adolescent not only to talk out his difficulties and relieve his repressions and complexes but one who will see to it that normal outlets of work and play are afforded, that opportunities are provided for the assumption of adult responsibility and for constructive, altruistic service, which it must be remembered is very attractive to young people. Without question a sincere religious experience aids as does nothing else in furnishing a motive for the control of emotion and imagination, in creating sound objective enthusiasm for chastity and in providing resistance and self mastery in temptation. Much of the current teaching in sex hygiene for adolescents and adults is based on the fear of the results of venereal disease. This may be legitimate, but at best it is negative teaching, and succeeds too often in substituting prophylaxis for clean living. Instruction in medical prophylaxis has never created a concept of the power and importance of chastity, and never will, and unless great emphasis is placed on these more spiritual phases of sex, very little real progress will be made. The following extract has been taken from H. G. Wells' protest against the dishonesty and inefficiency of modern society in handling the sex questions of children and youth.*

"The world has still to discover the scope and vastness of its educational responsibilities. Most of its teachings in these matters hitherto has been less in the nature of enlightenment than strategic concealment; we have given the young neither knowledge nor training, we have restrained and baffled them and told them lies. And then we have inflamed them. We have abused their instinctive trust when they were children with stories of old Bogey designed to save us bother that unrestrained youthful enterprise might cause, and with humorous mockery of their natural curiosity. Jocularities about storks and gooseberry bushes, sham indignations at any plainness of speech, fierce punishments of imperfectly realized offenses, this against a background of giggles, knowing innuendo, and careless, exciting glimpses of the mystery have constituted the ordinary initiation of the youth of the world. Right up to full age, we still fail to provide the clear elemental facts. Our young men do not know for certain whether continence is healthy or unhealthy, possible or impossible; the sex is still assured, with all our power of assurance, that the only pure and proper life for it is a sexless one. Until at last the brightest of the young have been obliged to get down to the bare facts in themselves and begin again at the beginning. . .

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* "Joan and Peter, the Story of an Education."

"So Joan, co-heiress of the Ages with Peter, found that because of her defaulting trustees, because we teachers, divines, writers and the like have shirked what was disagreeable and difficult and unpopular, she inherited nothing but debts and dangers. She had not even that touching faith in Nature which sustained the generation of Jean Jacques Rousseau. She had to set about her problem with Peter as though he and she were Eve and Adam in a garden overrun with weeds and thorns into which God had never come."

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HYGIENE OF INSTRUCTION

Reading. *Use of the Eyes in Reading.*—By means of an elaborate apparatus consisting of a camera with moving films, filtered light, mirrors, a kymograph, etc., it is possible to observe and record otherwise unseen movements of the eyes in reading.* The records (Fig. 252–256) demonstrate the fact that in reading there is not a continuous uninterrupted movement of the eyes from left to right, but that during the passage of the eyes across the page along a line of print 10 cm. in length there are from 9 to 6.7 fixations or pauses. These fixations are unrelated to words or phrases or sentences. They may be demonstrated imperfectly after overstrain of the retina from too great exposure to bright light, in the jerky movements of muscæ volitantes.† In the reading of adults, the last fixation of a line occurs considerably to the left of the end of it, the past reading experienced, supplying the material beyond.

As children inexperienced in reading are obliged to scrutinize all words, it is therefore desirable to supply them with books in which the lines are short. The section of line between two fixations or pauses is called the perception or attention span. The average attention span occupies 0.023 second. Rapidity of reading depends largely upon the length of this span, which can be increased with practice. During the attention span, the meaning content of the reading matter is registered but not comprehended. Comprehension and assimilation of material occur during the pauses. The pauses average 0.185 second in length. If the pause is too short, fatigue results, and there is a lack of time for proper assimilation, association, and memory organization. Rapidity of rate is affected also by regressive movements of the eyes. Regressive movements occur in children unaccustomed to language symbols, and in adults who need to comprehend more carefully.

By examination of Figs. 252–256 it will be noted that vertical lines cross the reading material at more or less irregular intervals. These lines indicate "fixation points." The number of the fixation is found above the line, the length of the pause in thousandths of a second below the line. Figure 252 represents silent reading by a rapid reader; Fig. 253 oral reading by the same subject; Fig. 254 represents silent reading by a slow reader. In Fig. 254 pauses 1 and 2, and 11 and 12, represent regressive movements. In Fig. 255 pauses 4 to 6 represent a gap in attention. In Fig. 256 pauses 8 to 14 represent minute analysis of words; pauses 5 to 1 represent a period of extreme confusion. Attention spans that are too short indicate that the efforts are expended in mastering the mechanics of words rather than the meaning. Words are the units of speech, but phrases are more often the units of meaning. It is for this reason that definite effort must be made to produce the habit of reading in meaningful units or phrases, which implies the longer attention span. If Fig. 252 and Figs. 254 and 256 are compared, it will be seen that the number of fixation pauses is increased in the latter; in other words, the length of the attention span is decreased with poor readers and with those who read aloud. This indicates that the reader is not free and familiar with his material, but, as has been said before, is obliged to analyze too closely. The average number of pauses in a line is eight; extreme cases register as many as seventeen or even more.

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* Gray, C. T., Types of Reading Ability as Exhibited Through Tests and Laboratory Experiments, Supplementary Educational Monograph in The School Review and the Elementary School Journal (August 29, 1917).

† Huey, E. B., "Psychology and Pedagogy of Reading."

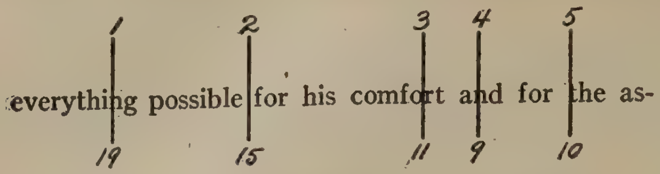

FIG. 252.—Silent reading, Subject B. Rapid reader.

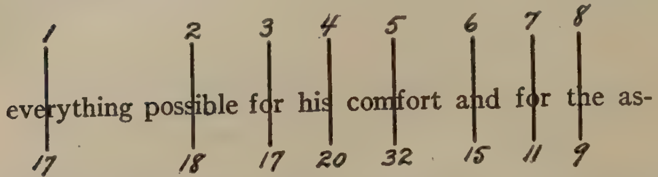

FIG. 253.—Oral reading, more fixations, slower. Same subject, B.

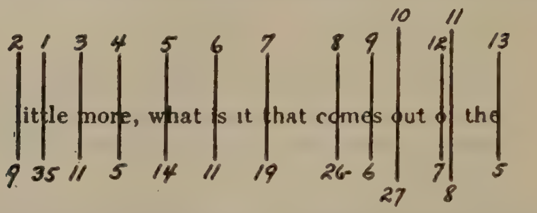

FIG. 254.—Silent reading. Slow reader. Regression pauses 1 and 2, 11 and 12.

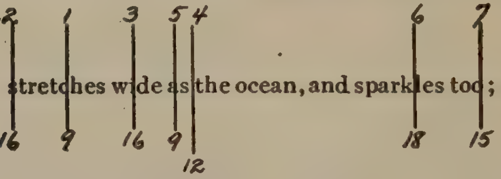

FIG. 255.—Gap in attention, pauses 4 to 6. Fair reader.

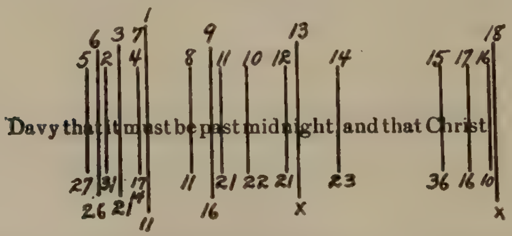
6 3 7 1 5 2 4 8 9 11 10 12 13 14 15 17 16 18
Davy that it must be past midnight and that Christ
27 31 17 26 21 14 11 11 16 21 22 21 x 23 36 16 10 x

FIG. 256.—Pause 8 to 14, minute analysis of words, 5 to 1, period of extreme confusion. Silent reading. Slow reader.

Another fault seen in Fig. 254 is that of backward movements of the eyes, or regressions, in which the first pause follows the second, and the eleventh follows the twelfth. This indicates that the eye has made a movement which does not fit recognition.* Such movements occur in children unaccustomed to language symbols, and in adults who need to comprehend more carefully. In order to get the word or letter necessary to complete recognition the eye must move back.

In Fig. 256 we have a notable example of confusion in which the child tries to comprehend a mass of visual sensations so unfamiliar that he flounders in his effort to cipher them out; and lastly, in Fig. 255 we have an instance of a fairly good reader whose fixation pauses occur for the most part with the syllables, an exception occurring between pauses 4 and 6, where there is a very long attention span during which the subject omitted to make any mental record of what she was reading, shown by the fact that when questioned she could not recall this section of the material.

Head movements, which occur in young readers, also retard the rate.

Inner vocalization is a very general accompaniment of silent reading, and is due to habits which the muscles controlling speech acquire in the practice of oral reading. It can be overcome by practice in silent reading with material that creates so much interest that the reader flies over it with a rapidity that makes inner vocalization impossible. The greatest amount of inner vocalization occurs in the third or fourth grades. At this period it helps to increase comprehension. As it hinders rapidity, however, close concentration in silent reading must be substituted for it. This may be accomplished either by interest in the subject matter, or by clearly understood effort with subsequent analysis, outline, or reproduction of the subject read.

In the case of reading defects it is desirable to make a specific diagnosis before trying to overcome reading difficulties. Except in the more pronounced cases this would involve the purchase of a reading apparatus which is expensive. Every school system, however, should be equipped for this diagnostic work, and the experiments would probably be made best in the Child Study Department. A very crude method of distinguishing reading defect is to place the subject directly in front of the examiner and have him lift the book or reading material very nearly to the level of his eyes. In doing so the upper eyelids are lifted, exposing the eyeballs. Thus, as he reads the lines, the eye movements can be observed and sometimes a rough diagnosis made.

Treatment.—For beginners, simple words should be used which involve action (run, hop, etc.). This can be reinforced by illustrative pictures and dramatization. Much emphasis is being placed upon

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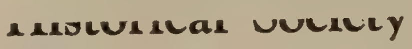
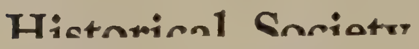
* Judd, C. H., "Reading: Its Nature and Development."

"Flash-word drill." In a study of reading conducted by Mr. W. L. Miller under the direction of Dr. W. S. Grey both of the University of Chicago, with borderline children in the Orthogenic School of Rush Medical College, it was found that relatively too much emphasis had been placed upon phonics and too little upon word presentation as a whole. It was quite clear from the study that short scrutiny of words when the child was concentrating was the best single method to pursue, relating the words, of course later to the content. Words of greater length and complexity are taught phonetically. After the fourth grade a distinct effort should be made to discover head movements and inner vocalization. If there is unusual difficulty, words are analyzed, prefixes and suffixes studied, words similarly derived are studied in groups—the dictionary being consulted—synonyms are found, idiomatic phrases compared, and silent reading practised largely to the exclusion of oral reading.





As future efficiency depends in a large degree upon rapidity and comprehension in silent reading, it is important that special training in this line be given. The most effective way of accomplishing this is by the reading of interesting material, with rehearsal of the contents later, so that a check may be made on the thoroughness with which the work is done.

The whole aim is to procure habits of long attention spans and short, well assimilated fixations, with resulting increase in a clear comprehension of subject matter, greater fluency, and less fatigue. Dr. Judd's book, which deals also with alexia, or congenital word blindness, is an exceedingly helpful presentation of the entire question.

The importance of readable type cannot be over-estimated. There is a great difference in the legibility of different letters. The most legible letters are w, m, q, p, v, j, and f. The letters h, r, d, g, k, b, x, l, n, and u are fairly legible, while the letters a, t, i, z, o, c, s and e are but poorly legible. C, e, and o are so much alike that they are easily confused, I looks like l, a looks like s, and h like b. In reading, the eye, as it moves horizontally across the page, focusses just below the top of the main part of the letters, and practically ignores the lower part. The above example illustrates this admirably, and shows how important upper prolongations are in giving meaning to the whole.

In order to avoid confusion of illegible letters, printers of school books have tried to give them more individuality and to make them therefore less fatiguing to the eye. Print, on the whole, should be much larger; the internal spaces of the letters themselves should be wider. Cohn and Graupner advise 1.5 mm. as the shortest height for single space letters at a working distance of 25 cm. This gives an optical angle of 2°. The largest optical angle (for primer letters) is 4.5 to 5.0°. For beginners, spaces between words should be wide also, so that the child may not be confused by the crowding of unfamiliar symbols upon the retina. The lines of print should be at least 2.5 mm. apart. Cohn has a test apparatus consisting of a white card in which a square 0.25 cm. in diameter has been removed. Through this space it should be impossible to see more than two lines at once.*

Huey gives the following sizes of print for school readers:

(1 point 1/72 inch)

Primer...............	18 point type	1/4 inch height	Letter l body of type
High first and second grades.............	14 point type	14/72 inch height	Children begin to read
Third grade...........	12 point type	1/6 inch height	

Print can be still smaller for older children.

In primers the leading should be twice the distance of the size of the letters. If care is not taken in regard to this point, children will isolate words by holding the book closer to the eyes, thus making the pictures of single words on the retina clearer. This practice, however, is harmful to the eyes, producing faulty accommodation, congestion, and myopia. Books should not be held closer than 12 inches. Some convergence is always necessary when objects closer than 18 inches are scrutinized.

When there is a *glare* on the printed page the reflected image is not accurately focussed upon the retina, because the eye is focussed for the printed matter. Therefore, the image of the light source is spread out over the retina forming a veil, which reduces the contrast. There is also the distracting effect due to the tendency of the eye to turn toward the glare spot. The glare also reduces the size of the pupil, all of which aids in producing eye strain in reading.† Books, therefore, should be printed upon flat, white paper. Polished surfaces, such as desks, smooth blackboards, glossy ink, and glazed paper particularly, reflect not only diffuse light but the image of the source of light, and are both fatiguing and confusing.

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* Kruse und Selter, "Gesundheitspflege des Kindes."

† Luckiesch, M., Glare from Paper, Fourth I. C. on School Hygiene, v.

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Arithmetic.—In mathematics all other facts concerning an object are submerged in the idea of quantity; objects become units, or multiplication of units (groups). Symbols of number are substituted for the name of the object; one symbol may stand for one object, while another symbol may stand for a group of objects. Addition and subtraction deal with units, multiplication and division with groups.

Arithmetic, therefore, involves a high degree of control in association. The solution of a problem may be reached only by the choice and logical sequence of a few related facts. Reason is a late development of the mind. Number work, therefore, should not be started too early, and should, in the earlier years, entail no grind. When problems are finally attempted it is unwise to push their solution with too much persistency. Periods of oral and written arithmetic should not follow each other, but should be interspersed with work which is less intensive.

The mental peculiarities that arise as a result of too much mechanical drill in arithmetic are usually of two kinds: (1) the counting habit; (2) arrests due to incorrect use of devices. The counting habit, or arithmomania, is a condition in which ideas of quantity fill the mind instead of ideas of cause. It is largely due to class work in concert with rhythmic emphasis, as in counting aloud or repetition of multiplication tables. Nervous children addicted to this habit may habitually count the planks in the sidewalks, or if they tap the floor with one foot a number of times they must tap as many times with the other foot.

Certain devices, which are valuable if properly used, may produce permanent impressions which are almost impossible to shake off. Norman Triplett* refers to a woman who had been taught to add and

* Pedagogical Arrests and Peculiarities, Ped. Sem. (1915), p. 141.

subtract by means of the abacus, and who was never able to eliminate the red and green balls from her mind whenever she found it necessary to add or subtract later in life. One little boy who was overtrained in number combinations told his mother that "Myrtle had combinations of five on her coat." Another child in the author's experience reached the solution of simple problems in addition by referring to the number of panes of glass in a specific window in his mother's room. There are many neurotic adults who involuntarily, or as a pastime, trace down all numbers that they see casually on the street or elsewhere to their least common denominator. Such habits obviously retard and arrest mental processes and involve a great waste of nervous energy.

Educational tests: Courtis Standard Research Tests in Arithmetic. Series B., Moody Arithmetic Scales.

See Bureau of Educational Research, College of Education First Annual Report (1919–20). Publ. by Univ. of Illinois, Urbana, Ill.

Monroe, W. S., Monroe Standardized Reasoning Tests in Arithmetic, Univ. of Ill., Urbana, Ill.

"Principles of Method in Teaching Arithmetic, as Derived from Scientific Investigation." Monroe, W. S., The Eighteenth Year Book Part II, Public School Publishing Company, Bloomington, Ill., 1919.

Cleveland Survey Arithmetic Tests. Public School Publishing Company, Bloomington, Ill.

Writing.—The hygiene of this branch is concerned with two factors: (1) Posture; (2) Eye-strain.

1. As it is a nervous strain for children to hold any fixed position for more than a short period, it is desirable in writing to find one "in which they may deviate in several directions, but from which they should not deviate permanently in any direction."

The head and body should be held erect during writing. If the back is bowed breathing will be interfered with, digestion disturbed, the abdominal blood vessels congested, and abdominal muscles lowered in tone. The center of gravity of the body in the sitting position should lie above and within the base of the pelvis. If there is too much leaning, either forward or backward, so that the center of gravity is displaced, there will be muscular tension with resultant fatigue.

Twisting or habitual side bending sometimes results in scoliosis, particularly in delicate children.

Requirements.—Seats should be adjustable, and should be so fixed that the feet rest squarely on the floor, the upper surface of the seat meeting the under surface of the thighs, with the legs at right angles to the thighs. If there is any back support during writing, it should be arranged so as to support the lower part of the back only. The top of the desk is best inclined at an angle of 15°, and should extend about 3 inches over the edge of the seat. The front of the body should touch the desk, facing it squarely. The height of the desk should be such that the arms may rest easily upon it without being elevated at the elbows or shoulders. The elbows should be held about 3 inches from the body. The right forearm should rest on the desk throughout most of its length, at an angle of 60° with the edge. The left forearm should also rest on the desk to assist in holding the paper.

The best type of movement in writing is called "arm movement with rest." By this is meant a rolling movement of the arm upon the pad controlled by the muscles on the front of the forearm. This movement gives not only firmness and evenness of line, but also regularity of slant, since it is produced from a center at a considerable distance from the penpoint.

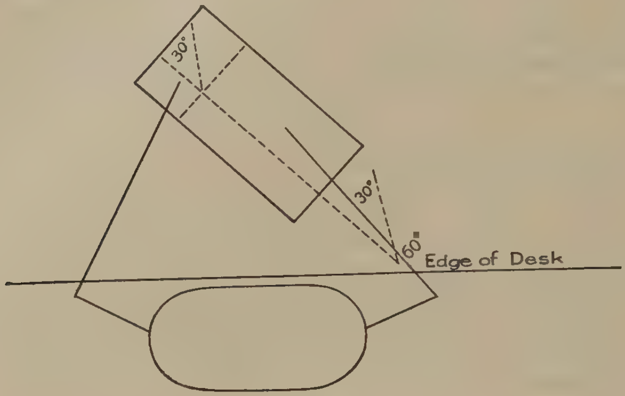

Fig. 257.

It is advantageous to adjust the arm so that the hand, in writing, progresses easily and smoothly along the line. It should rest, therefore, upon some freely sliding points of contact, such as the finger nails or side of the little finger. This position avoids cramping.

The fundamental accessory muscle theory is involved in this matter of writing movement. One school teaches that, in the beginning at least, only trunk, large, or fundamental muscles should be used in writing. This, however, is a very awkward practice, because finer finger adjustments are also necessary in producing good script. The other school advises the use of the accessory with the fundamental muscles, basing its theory and practice on observations of infants, who at a very early age use the small finger and hand muscles in grasping. They emphasize, however, the importance of relaxation in holding the pencil or pen. They advise that until the third grade only pencils should be employed in writing, that pens, when first used, should be coarse, the proximal end of the penholder made of cork or rubber, and the thickness such that it will not slip in the fingers, while permitting them at the same time to bend around it easily in a natural manner. They insist upon easy writing materials in the earlier grades, such as slightly rough paper for work with pencils, and hard paper for pen work. Their investigations show that precision and steadiness of movement are deficient in young children, and that the steadiness with which a child of six years can maintain any position is four times less than that of an adolescent. Children less than 9 or 10 years of age, therefore, should not be required to make movements which are very precise, rapid, or complex, or which demand great steadiness of adjustment.

Dr. Freeman summarizes these points as follows:

Primary grades: Large, free arm movements without precision.

End of third grade: Children accustomed to the use of the pen should write a large hand, making 50 well-formed letters in a minute, and should be able to express thought in writing.

Fourth grade: There should be much better motor control, the child now becoming interested in perfecting his writing, and submitting intelligently to drill in forming correct habits of movement.

High school pupils should be able to make one hundred letters per minute.

2. *Eye-strain.*—Requirements necessary to avoid myopia and eye-strain:

Eye-strain results from inequality of distance, as well as inequality of vision. In all eye functioning both eyes should be at the same distance from the point upon which they are focussed. It is important, therefore, that the paper in use should be held in front of the body. There is far greater danger that the paper will be held too far to the right than to the left. In either case, eye-strain and poor posture result.

Distance of copy from the eyes:

Minimum for the adult	16 to 20 inches
Minimum for grammar grades	14 inches
Minimum for intermediate grades	12 inches
Minimum for primary grades	10 inches

On account of the natural hyperopia of the eyes of children under 7 years of age, it would be desirable to have the copy held still farther away. Because of the child's size, however, 10 inches is the greatest distance that is compatible with the correct use of the arm. The habit of many hyperopic children of bringing the eyes much closer to the copy than 10 inches should be corrected.

Size of Letters.—Primary: One space letters as *a* should be ½ inch high.

Third grade: One space letters as *a* should be ¼ inch high.

Upper grades: One space letters as *a* should be ⅛ inch high.

Spacing of Lines.—Primary: If ruled paper is used, the lines should be 1½ inches apart.

Third grade: If ruled paper is used, the lines should be 1 inch apart.

Upper grades: If ruled paper is used, the lines should be ⅜ inch apart.

Slant.—Vertical and slanting script.

Vertical script is that in which the down strokes of the letters are at right angles to the edge of the paper or line of writing. Vertical script has been advocated largely because some investigations have shown that in schools where it is taught the percentage of scoliosis is less than in schools teaching diagonal or Spencerian script. The

Wundt-Lamansky law states that the eyes move most freely in a vertical or horizontal direction. The line connecting the center of vision of both eyes is the basal line of a plane which is projected to the writing paper. If the head is held erect, and the edge of the paper is parallel with the edge of the desk, this plane will coincide with the line upon which the writing occurs. The vertical slant, however, is very difficult to keep uniform, unless the paper is held somewhat to the right. Pedagogists prefer the slanting type of writing because it is necessary to have the paper in such a relation to the forearm that when it rotates about the elbow as a center it will carry the hand along the line of writing, thus decreasing fatigue. As a matter of fact, it has been demonstrated that if the paper placed directly in front of the writer is turned 20 or 30° to the left, with the right forearm at an angle of 60° with the desk (Fig. 257), the down strokes of the letters take a direction approximately perpendicular to the edge of the desk when it is faced directly. It is also maintained that the lower edge of the plane projected from the basal line connecting the eyes tends to be perpendicular to the *down stroke*, which is the guiding stroke, instead of the ruled line of the paper. The most natural direction of the upward and downward strokes of diagonal writing is toward the body, or approximately at right angles to the edge of the desk. This makes the writing deviate by the same angle that the paper is tilted.

Speed.—Pupils should write slowly enough to enable them to make letters with some semblance of their true form, and with some regularity.

Medium grammar grade	200 double strokes per minute.
Lower primary grade	100 double strokes per minute.

The correct procedure in teaching writing is to choose some simple word which is already of significance to the child, write it for him on the board, have him attempt to copy the word by imitating the action, and finally lead him to criticize his own products, so that he may intelligently choose a procedure which will produce improvement.

Fatigue always appears earliest during the first learning periods of any subject. In the first five grades there should be frequent writing periods of 10 minutes; in the elementary school, periods should never be longer than 20 minutes.

Tests for writing ability: Thorndike's Scale for Measuring the Handwriting of Children in Grades Five to Eight. Teachers' College, Columbia Univ.

The Freeman Chart for Diagnosing Faults in Handwriting. Univ. of Chicago.

Freeman, F. N., "A Course in Handwriting." Elementary School Journal, vol. xxii, Nos. 5, 6, 7, 8, Jan., Feb., March, April, 1922. (University of Chicago.)

See also The Eighteenth Year Book, Public School Publishing Company, Bloomington, Ill., 1919.

Spelling.—Some children learn to spell more easily through their eyes, some through their ears, some through corresponding movements of the face and throat. Therefore, in group work especially, it is important to present the printed word, to speak it, and to write it simultaneously. Lay's spelling experiment, which illustrates these facts is, as follows:

TABLE 35.—PERCENTAGE OF ERRORS PER PUPIL

Hearing—without speech movement	3.04
Hearing—speaking low	2.69
Hearing—with loud speaking	2.25
Seeing—without speech movement (reading)	1.22
Seeing—speaking low	1.02
Seeing—speaking loud	0.95
Seeing—copying, speaking low	0.54

It will be seen that the combination of seeing, writing, and articulating produces the best results.

The best single method of spelling is by drill in which words are divided into syllables. The principles of the drill method are "sufficient repetition, adequate attention, and avoidance of wrong associations." If the children are old enough to understand the significance of prefix or suffix, its meaning should be explained, so as to make the performance as little that of rote memory as possible. In every other way also, meaning should be associated with the word. The words should not only be presented as column drill, but with the latter it is important to present them in dictated sentences so that their relation may be comprehended. Spelling will be vitalized if it accompanies reading and writing and geography.

Drill should be directed first to words in common use in the community. There should also be separate lists for younger children, for advanced spellers, for foreign children, and for those preparing for vocations which require a specialized vocabulary. Incorrect spelling should always be corrected, and record charts should be used by means of which the child can watch his own progress.

Reviews, spell-downs, and inter-school spelling contests can occasionally be introduced as stimulants.

Many schools teach spelling only in connection with reading, etc., until the age of 10 years, after that introducing drill periods of 15 minutes a day. This doubtless answers very well for good spellers, but would be totally inadequate for poor spellers, who require drill from the outset.

Horn, Ernest, Principles of Method in Teaching Spelling as Derived from Scientific Investigation. (Excellent bibliography.) The Eighteenth Year Book, Part II, Public School Publishing Company, Bloomington, Ill., 1919.
Freeman. F. N., "Psychology of the Common Branches."
Wallin, J. E. W., "Spelling Deficiency."
Heilmann, J. D., "A Study in Spelling." Research Bulletin No. 2, Colorado State Teachers' College Bulletin.
Ayres, Spelling Scale.

See bibliography in Educational Tests and Measurements, Beeson, M. F., Research Bulletin No. 7, Colorado State Teachers' College.

THE KINDERGARTEN

The Kindergarten was originated in Germany by Friedrich Froebel, at about the beginning of the nineteenth century. His philosophy was based upon the supposition that the child is born with a certain ability to conceive abstract ideas. For the development of these conceptions, and also to embody or symbolize them, he evolved play material which he called gifts* and occupations. The ball, for instance, expressed the idea of infinite development and absolute limitation of unity; the cube symbolized the idea of multiplicity not only to a philosopher but also to a little child.

On the other hand, he taught that social experience was neither an influence nor a determinant in human development, that rather all knowledge and all the activities of life come from within and must have free expression. He advocated, therefore, placing material before the child and allowing him to work it out according to his own fancy. Out of this theory grew the practice of laying stress upon freedom, self activity, initiative, purpose, and creative power, all of which are great factors in the mental growth of the child and are recognized as representative principles in modern education.

Graves' "Proceedings of the Twenty-third Annual Meeting of the International Kindergarten Union," p. 53.
Temple, Alice, "Survey of the Kindergartens of Richmond, Indiana."
Brown, Grace L., "The Play Motive and Experimental Method in Kindergarten Occupations," "Experimental Studies in Kindergarten Education," Teachers' College, New York City.

In his studies with Pestalozzi, Froebel had seen the importance of sensory training and of manual activities. Upon this he worked out a system of nature study, through which he expected to develop the child's esthetic nature and love for animals. He also published a book of songs (Mutter und Kose Lieder), and collected stories for dramatization by which he intended to develop the child's imagination. Above all, however, he demonstrated the power of play in producing interest, concentration, and moral adjustment (article on Play, p. 1070). In other words, Froebel sought to give the child experience rather than instruction, and to educate him by motor and sensory activity rather than by books. To develop this activity as has been said he devised play materials of two kinds: gifts and occupations.

The gifts:

First, the ball—six woolen balls of six different colors, three primary, three secondary. Froebel regarded this form as the one from which all other form was developed. Miss Elizabeth Harrison says: "With the ball is taught possession and loss, consciousness of self and not self, position and location, 'here—there;' time and rhythm, 'now—then;' space, 'near—far,' 'up—down,' 'high—low,' 'round and round.'"

Second, a box containing a sphere, a cube and a cylinder. Through them, differences of shape and movement are discovered. Angles are learned. The cylinder is seen to comprise both the ball and the cube, from which the later gifts are developed.

Third, a wooden cube of 2-inch dimension divided into eight small cubes of equal size. The idea of this cube is that of a whole and parts.

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* Kilpatrick, W. H., "Froebel's Kindergarten Principles Critically Examined."

Combinations of one-half, one-fourth, and one-eighth are learned. The small cubes serve also as building blocks.

Fourth is a cube made up of eight oblong parallelopipeds. These teach length, breadth, and height, communicated motion, balance, and vertical building. With them can be demonstrated divisions of the cube, enclosure of space, extension plays, surface movements, etc.

Fifth is a development of the third, and is composed of twenty-seven blocks, some of which are triangular.

Sixth is a development of the fourth, and is composed of twenty-seven oblong parallelopipeds about ½ inch in thickness.

Seventh, surfaces—quadrangular and triangular tablets of thin wood.

Eighth, small sticks or laths, ¼ × ¼ × 6 inches. These represent extension only.

Ninth, circular and semi-circular rings.

Tenth is a seed or lentil, in which dimension is reduced to a point. (H. M. Mills).

The gifts were used also to represent objects and activities that are connected with human relationships, such as the construction of houses, churches, enclosures, and furniture—"life forms."

The *occupations* are devices of paper cutting, folding, weaving, and paper sewing, through which Froebel expected the child to express himself. They are intricate, easily torn, and some of them exceedingly difficult even for adult hands. They have been largely discarded.

The Gifts and Occupations violate:

1. The *Pedagogical* principle, that whatever is the best educational method or device for one stage should be the best preparation for the stage that follows it. Froebel failed to see that both gifts and occupations were meaningless material and could carry over only such values as might be gained by playing with toys of any kind.

2. The *Physiological* principle, that little children cannot advantageously handle small objects that require precision of movement. The smallest gifts are only ½ inch in their longest diameter. As has just been said, the occupations are intricate, deal with very perishable material and require such nicety of adjustment as is found difficult even by adults.

Miss Elizabeth Ross Shaw says: "The gifts are fetiches of an esoteric cult. In glancing through the Annual Report of the International Kindergarten Union, and the Kindergarten Report of the Commissioner of Education for 1916, I found it very significant that the 'gifts' are not once mentioned in them."

In April, 1909, Dr. I. A. Abt published an article entitled "An Inquiry into the Status of the Kindergarten." The data for his investigation were largely obtained by means of a questionnaire sent to physicians, educators, kindergarten teachers, first-grade teachers, and mothers.

The following subjects are considered in his article:

1. Age limits.
2. School conditions.
3. School attendance (regularity—effect of weather).
4. Kindergarten and infectious diseases.
5. Kindergarten and nervous children.
6. Kindergarten and overstimulation.
7. Bad influences of the Kindergarten.
8. Favorable influences of the Kindergarten.
9. Factors which make the Kindergarten desirable.

The conclusion of the investigation was as follows: "The desirability of the Kindergarten depends upon the state of health of the child, the qualifications of the teacher, the disposition and capacity of the mother, the environment of the home, and the equipment of the Kindergarten.

1. The consensus of opinion is that four to five years, preferably five years, is the proper age for admission.

2. "We must insist upon proper hygienic surroundings for these children, even though their hours are short, because it is here that an impress—a most undesirable one—may be made on the child's physical health, from which recovery is not only protracted, but may be impossible."

3. About two-thirds of the children remain in attendance through the year. The main reasons for falling off in attendance are inclement weather and winter exodus of well-to-do parents to warmer climates.

4. Contagious diseases cause by far the largest number of absences.

5. Nervousness among healthy children causes practically no absences unless home conditions predispose to nervousness.

6. On the other hand, nervous children may become more excitable, more restless at night, or they may acquire habit spasm. The teacher's personality has a profound influence upon such children.

7. Baneful influences are exerted by very fine hand work, long periods devoted to such work, too many subjects in the curriculum, too much specialization, too many teachers, too much "showing off" of the children at exercises for the benefit of visitors, too many normal school students observing the children at one time, too much hurry and bustle, too closely following a set program, and too little play.

8. Points in favor of the Kindergarten: it teaches the child to observe in a logical, profitable way; it inculcates habits of discipline and obedience, observation and thought; it imparts a training that cannot, as a rule, be received at home, affords opportunity of social contact with children of like age, teaches self-control, makes the child democratic, independent, purposeful (especially in the case of backward children), gives them new ideas, makes them creative, encourages mental and physical development, and is a logical link between the home and the school.

This article of Dr. Abt's was a great stimulus, producing among

Kindergarten leaders a wholesome reaction toward a type of activity based upon child study with special emphasis on his physical equipment. The statement of Miss Patty Smith Hill, Director of the Kindergarten Department of Teachers College, that "Kindergartners are trying to get away from every system except the nervous system," has become classic among them.

The actual changes that have occurred in the methods of Kindergarten instruction are the following:

1. Gifts are placed in the background.

2. Size in gifts is greatly increased. The first departure from the gifts were enlarged blocks designed at the School of Education, Univ. of Chicago, having the following dimensions: cubes, 6 × 6 × 6; parallelopipeds, 12 × 6 × 3; pillars, 12 × 3 × 3; tablets, 6 × 6 × 3; and boards for roofs, 3 feet × 6 × 1 inch. Tables, chairs, etc., are made large enough to fit the children, and the children themselves build houses which are large enough to play in. In the Kindergarten Department of Teachers College, New York City, children are sent out to observe such complicated structures as a Fifth Avenue bus, so that they may reproduce them with blocks.

3. All Froebelian "occupations" as such are eliminated.

From a constructive point of view the Kindergarten presents to the child organized schemes of play and work known as (p. 1062) objective projects* based upon those experiences of the home with which he is most familiar. These schemes are progressive and include activities that carry him out beyond the home into those of the neighborhood and community of which he is becoming an integral part.

The Kindergarten of the Department of Education of the University of Chicago, under the direction of Miss Alice Temple, has developed the following curriculum, based upon the psychology of the child from four to six years of age.

The daily program is as follows:

9:00– 9:10 Informal social period.

9:10– 9:30 Greetings and rhythm period (songs).

9:30–10:00 Morning exercises or conversation period.

10:00–10:15 Recess and lunch (one Graham cracker while playing about).

10:15–10:50 Hand work, block building.

10:50–11:10 Out-of-door play or indoor games. If the former, children have not only the advantage of greater freedom and limitless fresh air, but they also have the experience of putting on and removing their outer garments. If the latter, games are played with windows wide open. If at all possible, play at this period occurs out of doors. The children are free at this time to play as they wish.

11:10–11:45 Hand work again.

11:45–12:00 Story and dismissal.

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* Parker, Samuel Chester, Project Teaching, Pupils Planning Practical Activities. Elementary School Journal, xxii, Nos. 5 and 6 (Jan. and Feb., 1922).

This program progresses definitely throughout the year. The fall program deals largely with the social subject of food supply and its preparation in the home, the grocery and farm being sources of supply. Excursions to these places are taken, and the projects worked out from the observations of the children and teachers together (Fig. 21).

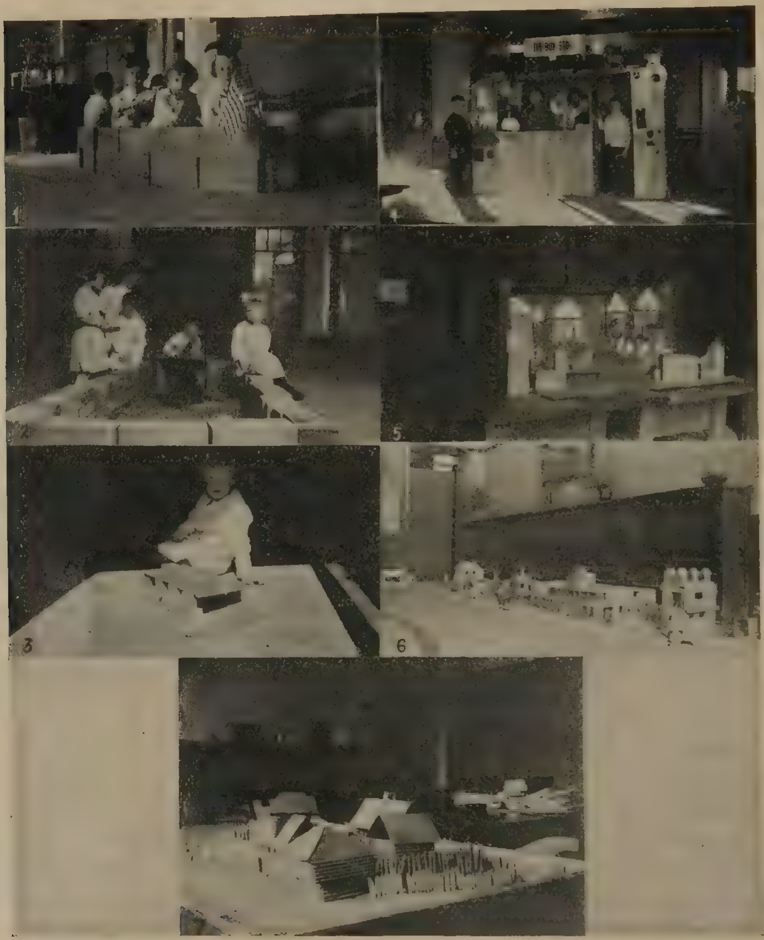

FIG. 258.—1. Boat—a group project. 2. Hen yard—group project, nature study. 3. Street car—individual project. 4. Store, group project. 5. Interior of Kindergarten—(note bench for visitors, piano, etc.). (From Kindergarten School of Education, University of Chicago.) 6. Flat building—school, church and house. Opp. side; grocery store, etc. 7. Model of first Fort Dearborn after Whistler's etching and model at Chicago Historical Museum. Project in sand table; fence made of broom corn centers and houses of corrugated card board. Devised by older "Borderline" children in Orthogenic School, Chicago.

In the winter program the subject matter deals with the homes and stores of the community, community activities, the care of streets in winter, the ways of communication from house to house, the work of the postman and the assembly of large groups of people in community buildings. The spring program centers about the home and garden and also considers ways of communication from one city to another.

Materials used in the Kindergarten are clay, sand, nature material, (leaves, grass, etc.), blocks for building, paper construction, dolls and paper dolls for dressing, textile materials and wood work material. The out-of-door equipment consists of slides, swings, see-saws, all built close to the ground, and a fence 3 feet high on which to climb and walk. The fence should be finished on top with a 6-inch board for balance work. Indoor baseball is played.

G. S. Hall advocates a stone and wood yard in which there are stones varying in size and weight, some as heavy as a child can lift and some as small as pebbles. It should also contain glass, ore, minerals, fossils, arrow heads, slings, and clubs. In winter advantage should be taken of snow for the purpose of digging, rolling, and leaping. Snow is also excellent material with which to make letters, snow images and cart wheels. Snow air is invigorating and free from germs.

KINDERGARTEN HYGIENE

The Teacher.—G. S. Hall says,* "So far as my acquaintance and personal impressions go, Kindergartners are, perhaps on the whole, the most womanly and motherly representatives of their sex to be found in modern society. They should know something about children, their teething, milk supply problems, atypical and subnormal children, common diseases, emergencies, cuts, bruises, burns, bandages, etc. They should be able to answer intelligently practical questions of younger mothers on such topics as hammocks, perambulators, orthopedics, institutions, weaning nipples, and adenoids, outline the regimen for impending motherhood and parental care, the social and sanitary environment of the child and neighborhood, feeding at home, etc."

Housing.—If the Kindergarten cannot be out-of-doors, it might, at least in winter, be above the top floor, under a roof wide open to the light, similar to some of the health provisions of hospitals. Winchester Schofield† reports that responses to a questionnaire indicate that most Kindergartens are having as much activity in the open air as possible. In the free Kindergartens in Hawaii, bathing suits are included as part of the regular equipment.

Sub-committees on Health Sanitation and Hygiene of the I. K. U., 1916, are issuing a bulletin on Kindergarten rooms, buildings and equipment, for the Bureau of Education. The bulletin covers the following topics:

1. What a modern Kindergarten stands for in physical conditions and provisions for indoor and out-of-door activities.

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* "Educational Problems."

† Kindergarten Education, Department of the Interior, Bureau of Education, Chapter xviii, i (1916).

2. Location and housing.

3. Room or building: rooms specially planned, rooms adapted, open air Kindergarten.

4. Out-door features: garden, playground, roof garden, apparatus, sand pile, pets and their housing.

5. Equipment.

6. Sanitary measures: ventilation of old and new rooms, heating, cleaning, disinfecting, toilet supplies.

The Kindergarten room of Teachers College is approximately 70 × 40 feet with south exposure on the broad side. If possible, the Kindergarten room should be somewhat remote from other rooms. The floor should be washed daily and the sand or sand piles should be discarded once a month or baked ("Sanitation of School Buildings," p. 1080).

Length of Periods.—It will be noticed in Miss Temple's daily program that the work periods last 35 minutes, rhythm work 20 and 30 minutes, recess and lunch 15 minutes, story 15 minutes, and greetings 10 minutes. As a considerable part of the time devoted to hand work is consumed in getting out materials, in inspection and comparison of the other's work, etc., the actual length of the period is not unreasonable. In the Montessori Schools, in which for the most part there are younger children, periods are not well defined, the children being free to work when they choose. The Montessori Schools are also provided with washable rugs which they spread on the floor and on which they may lie down. "This is in order that their bodies may not be taxed by remaining in one position too long. The freedom thus given to the impulse to change the muscular strain of his body whenever the child so wishes (an excellent point) is an advance over and above the amount of freedom allowed in the ordinary Kindergarten."*

Home Reactions.—If the Kindergarten child sleeps soundly, is not irritable, gains in weight normally, has good color, and is not easily fatigued, the experience may be regarded as desirable.

During the year 1914–1915 the number of the Kindergartens increased from 8825 to 9486, with an increase of 21,000 children. Six hundred and twenty of these Kindergartens were public, 41 private. Those states, with the exception of Nebraska and Rhode Island, that have no special legislation on the matter have the fewest Kindergartens. There are at present 4,000,000 children of Kindergarten age unprovided for.†

MANUAL TRAINING

At the present time this is a very generally and very well established part of the school curriculum, and it is an educational factor of no mean importance. It has acquired its reputation for the following reasons:

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*Harrison, E., U. S. Bulletin, (1916).

†For methods of securing Kindergarten legislation, see Reprint from Report of Commissioner of Education (1916), Chap. xviii, i, Kindergarten Education.

1. It develops the constructive instinct.

2. It familiarizes the child with the materials of art and industry.

3. It quickens sensory development and the development of perception. The imagination of little children is so great that it is difficult for them to grasp clearly the elements of the materials or objects that they handle. Construction work forces them to see the component parts of things distinctly and intelligently. It supersedes the wantonly destructive tendency of the child, which is usually nothing more than a manifestation of curiosity, by intelligent discriminative analysis of objects, or by the union of parts of objects into a significant whole. This aids in establishing mental habits that are healthfully objective, rather than subjective, and it aids in producing constructive imagination (Hygiene of Instruction).

4. The power of sustained attention is greatly increased on account of the child's natural curiosity and interest in objects.

5. Motor training, which involves simultaneous training of the attention, develops motor control by acting through nerve and muscle. Experiments in sawing wood have been made by R. R. Row* for the purpose of securing data on the effects of the use of tools in the development of motor ability. The subjects were given very accurate directions, were made to work under the same conditions, and all used the left hand so as to eliminate differences in already acquired ability. The charts,† made on a basis of time and accuracy, show a decrease in the time curve and an increase in accuracy. Uniformity and steadiness were also acquired in continued motor activity. Whenever reflex or random movements of children are replaced by voluntary efforts a far greater degree of efficiency is reached.

6. Judgment is developed because of the difference in the fitness of materials, of distances, and of the cost in time. Further, the higher purposive or reasoning processes are involved because it is necessary to look ahead, not only to the finished product as a standard of comparison for each step of the process, but also to the value of the product to the outside world. This is especially true in older children, though all mechanical problems no matter how simple involve some thinking. Modern mechanical toys designed for construction work involve great mechanical principles, as for instance leverage, inclined planes, pulley, roller, wheel and axle, and clamp devices. These principles are likewise employed in many very primitive devices with which the child plays.

7. Morally, children are signally developed by both their successes and failures in manual work, probably because results are tangible and cannot be easily concealed. Bluffing is practically impossible. In a technical High School in Chicago every imperfect article, no matter how slight the imperfection, is ruthlessly broken and thrown into the junk pile. With little children, precision of technique is not warranted;

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* "The Educational Meaning of Manual Arts and Industries."

† Row, p. 80.

in children of this age a few materials for construction purposes are better than a large number, because the child's resourcefulness, self-reliance, and sense of power are stimulated, and growth of the child's nature occurs with the overcoming of increasing difficulties.

8. Manual training acts as a magnet in procuring school attendance. A Report of the Committee on Vocational Education of the Illinois State Federation of Labor, 1914, makes the following statement: "The child labor problem is intimately associated with schools. Reliable investigations and authentic reports evidence that only 7 per cent. of the children who enter the public schools ever pass through them. Not more than one-third of the children who enter the public school even finish the elementary grades, and not one-half of them finish the sixth grade. In Chicago, 43 per cent. of our children never reach the eighth grade, and 49 per cent. of these never finish it." With these facts under consideration, and the further fact that some children have anti-social tendencies, particularly disadvantageous from the nervous point of view, the benefits of hand work with its power of attraction to the individual and its possibilities for happy group and team work are obvious. An experiment illustrating the desirability of group work, as demonstrated both to the class and to outside observers, was made in the sixth grade of the Agassiz Public School, Boston. The special industrial class was given an order for 750 paper boxes. They worked both as specials and in a group, but they soon learned that when they were working toward a common end, each with his own responsibility, there was greater economy of material and time, that skill increased more rapidly by repetition of the same act many times, that there was a standard of accomplishment established below which no self-respecting boy wished to fall, and that no *good* box could be produced if any boy did poor work.

9. The value of manual work as an impetus to esthetic development must be self evident. Color, light and shade, form, design are all coupled with the making of practical objects, and a further appreciation of good art is increased.

Methods vary with the age of the child, but there is always an effort to correlate the hand work activity with that of other departments in the school. English measurements, natural history, a study of animals,—as for example, the fleece of the sheep in relation to textiles—all enter into education through manual work, so that the ordinary academic studies, as John Dewey says,* are vitalized by it.

Projects such as "The Village Street," so planned that each child in the group may be made responsible for a store, a house, a blacksmith shop, a flour mill, a fire department, or a carpenter's shop are typical of the best work in these lines for younger children. The subject as related to the education of little children is delightfully handled by Ella V. Dobbs, of the University of Missouri, in her book entitled "Primary Handwork." In this she describes the making of booklets, posters, the use of sand tables, clay, rug weaving, simple woodwork, and the artistic uses of paper.

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* Some Dangers in the Present Movement for Industrial Education, Child Labor Bulletin, i, No. 4.

The National Education Association, July, 1910, has published a Report of the Committee on "The Place of Industries in Public Education" which is very helpful. The place of industries in the Elementary School, the prevocational class, and the High School is discussed in a report of a sub-committee from an evolutionary point of view, *viz.*, from that of the activities of the race in its various stages of development. The progressive character of industries appears in a Study of Textile Industry. The neighborhood approach (see projects), garden work, ceramic industries, printing, a study of the foundry, etc., is found in "Manual Arts and Industries," by R. R. Row. P. B. Ballard's "Handwork as an Educational Medium," Miss Katherine E. Dopp's "The Place of Industries in Elementary Education," and the Manual Training Magazine all supply helpful outlines and full directions for this phase of education.

SPECIAL CLASSES

A representative law regarding special instruction for the blind, deaf, and mentally deficient has been made by Pennsylvania which reads as follows:

"Pennsylvania; Section 1413 of the School Code. It shall be the duty of the county or district superintendent, attendance officer or secretary of the board of school directors, in every district in this Commonwealth, to report to the medical inspector of the school district every blind, deaf, or mentally deficient child in the district between the ages of eight (8) and sixteen (16) who is not properly educated and trained. The medical inspector of the school district shall examine such child and report to the board of school directors whether it is a fit subject for education and training. If the child is reported to be a fit subject for education and training, but cannot be properly educated and trained in the public schools of the district, the board of school directors shall secure for it proper education and training: Provided, that when it is necessary to educate and train such children outside of the public schools, their parents or guardians shall, if able to do so, pay to the district the expense necessarily incurred by it in educating and training the same; and provided further, that any child who is reported by the medical inspector of the school district not to be a fit subject for education and training shall be exempt from the provisions of this act."

The Blind.—Special classes for the blind are provided in many large cities as a part of the public school system. Blind pupils are divided into two groups: totally blind and partially blind. The totally blind are provided with the Braille system of raised print, typewriting and raised paper. The partially blind are placed in especially well lighted rooms; they are provided with books printed in large strong type; their home work is done in school, and they have special help from their teachers. All blind pupils are taught reading, spelling, arithmetic, geography, grammar, history and music in the same way, and so far as possible to the same extent as normal pupils. The younger pupils are taught bead work, cord and raffia work, the weaving of mats, rugs and table scarves, different stitches used in sewing, and the making of caps and aprons that are used in connection with domestic science courses.

The physical education equipment is the same as for normal pupils, and it is astonishing to see the freedom, accuracy and agility of those more practised on the playground, in the gymnasium, and on the athletic field.

The classrooms are provided with especially comfortable furniture, and cots are arranged in the rest room for delicate children. Some schools provide a home investigator and teacher.*

The Deaf.—Special classes for the deaf consisting of 8 to 10 children have been established in most large cities. Among the 300 children in these special classes in Chicago, 15 or 5 per cent. come from families in which there are from one to three other deaf children. About 60 per cent. of the children in these families are slow or backward, 40 per cent. are bright. It is not known whether retardation in the deaf is due to language difficulty or to native mentality; it is found, however, that work in mathematics is probably as retarded as work in language, though this may be accounted for by the fact that number work has been neglected for the sake of language. Doubtless some of the retardation is due to faulty memory. This in turn is due to the loss of auditory sensation and perception, chief avenues of mental development.

It has been found that special classes for the deaf should be consolidated or centralized on account of the grading. Most of these centers are in public schools for the normal, but they have their own supervisors. The Boards of Education obviate the added expense of transportation by providing carfare and attendance fees.

On account of retardation special stress is laid on sensory development, on manual training, rhythm and dramatization. After being in school eight years they are ready for the fifth grade and may undertake the regular work of this grade in the public school. The Board of Education of the City of Chicago has outlined "A Course of Study for the Deaf," which is very suggestive. Miss Caroline A. Yale, Principal of Clarke School for the Deaf, Northampton, Mass., has published a manual widely used entitled "Formation and Development of Elementary English Sounds." Miss Martha E. Bruker of Boston, Mass., is one of the foremost advocates of the Müller-Walle Method of Lip Reading, now quite extensively used in most schools for the deaf. The Volta Review published in Washington, D. C., by the Volta Bureau is the recognized organ for the publication of material pertaining to work of this character. The bureau is headquarters from which may be obtained any information pertaining to this phase of defect.

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* Roberts, E. L., Medical Inspection of Schools in Great Britain, Dept. of the Interior, Bureau of Education, Bulletin No. 49 (1916), p. 30.

The Crippled.—In presenting the education of crippled children, it is necessary to consider the following factors: centralization, buildings and equipment, mental status, school curriculum, health and transportation.

In cities large enough to maintain special classes for crippled children it is desirable to have a *central school*, for at least three reasons: First, crippled children require the undivided attention of one principal, because each child is not only a pupil, but also a patient who requires individual prescription and treatment, part of which, if not all, must be given under the roof of the school.

Second: all handicapped children require segregation, otherwise they are continually depressed by the constant comparison with normal children with whom they cannot compete on the same terms.

Third, there is an enormous economy from the point of view of equipment and special teachers.

Advantage of *local rooms* in the graded schools: economy in transportation.

Buildings.—It is better to have two-story buildings. Crippled children find the distances necessary to walk in one-story buildings almost prohibitive. It is important that the buildings should be equipped with stairs, as the children need practice in stair-climbing. Planes also, and an elevator, are provided in the most modern buildings. Rooms should be provided both for individual corrective work and class work; other rooms with fairly high ceilings should be provided for factory wood work. Rest rooms and bathrooms, and rooms for the work of the nurse, are very essential, as well as space for domestic science and domestic arts.

Equipment.—For Domestic science.

Domestic arts (design).

Manual arts and occupational therapy (weaving, basketry, lace making, sewing, embroidering, etc.).

Business—book-keeping, typewriting, shorthand, comptometer, adding machine, dictaphone, multigraph, etc.

Trades—printing (The Jesse Spalding School of Chicago has a printing equipment valued at $2000); cobbling; wood work (the above school has band saws, turning lathes, grind stones, etc.).

Manufacture of toys.

Leather tooling.

Equipment for Physical Education.—Apparatus for the accurate measurement of paralysis.

Tables for massage, corrective work, and therapeutic light.

Complete apparatus for class work in scoliosis (rings, ladders, etc.).

Play apparatus, including everything except the giant stride.

School Curriculum.—Usual elementary school work, and special high school work.

Mental Status.—Ten per cent. of these children are feeble-minded, largely due to infantile spastic paralysis.

Health.—The Jesse Spalding School was purposely placed within a half block of a highly creditable Home and Hospital for Crippled Children. This is mutually advantageous, as ambulatory patients of the Home are able thus to attend school.

Corrective work in this school, for which there are seven physical education experts, is done only under prescription. Children are taken by the motor bus to the orthopedic surgeons of the various well accredited hospitals for observation and further advice, by the physical education teacher who has the case in hand. As a rule children with tubercular sinuses are taken to the Municipal Tuberculosis Dispensary for dressings, though in some cities an especially appointed school nurse does this work at the school.

Medical inspection occurs daily, with the primary object of discovering communicable disease. Superficial medical examinations are also made for physical defects. If these are found, they are corrected at well accredited general dispensaries.

Appliances are usually procured at minimum cost. The Jesse Spalding School has an arrangement by which the instrument maker is assured of payment for the brace, by money contributed by a Woman's Club which can be loaned parents by the Principal until payment is secured. The pecuniary condition of the family is investigated by the school or some hospital social service worker.

School Lunches.—Lunch of milk or cocoa and crackers is provided at recess, and a hot mid-day meal. Children are weighed and measured each month.

Transportation.—The cost of one motor bus with attendant is $32.50 per day. This could be reduced by arranging the busses with adjustable or movable seats, using the busses during school hours as motor trucks.

PHYSIOLOGY OF EXERCISE

The especial organs or structures involved in physical exercise are:

1. The respiratory system.
2. The circulatory system.
3. The neuromuscular system.
4. The thermal system.
5. The digestive system.

The Respiratory System and Exercise.—Within the thorax there are two types of atmospheric pressure: First, that called intrapulmonic pressure; second, intrathoracic pressure. The former is confined to the air passages from the mouth to the alveoli inclusive and is equal to one atmosphere, both at the beginning and end of inspiration and expiration when movement of the chest has ceased and outside air is for the time stationary within the chest cavity. On the other hand, *during the act of inspiration*, while the air is flowing in, intrapulmonic pressure falls because the air passages, even normal air passages, restrict the column of air more than it is restricted outside. This is especially so if the inspiration has large amplitude. During the act of expiration, the chest wall follows down the chest contents more rapidly than the air can escape, therefore the pressure within the chest cavity is greater than the atmospheric pressure outside.

Intrathoracic pressure is the pressure in the pleural cavity and mediastinal space and is exerted mainly on the heart, great blood vessels, thoracic duct, esophagus, etc. It is the equivalent of intrapulmonic pressure or one atmosphere, minus the elastic pull of the lungs. This minus quantity, produced by the elastic pull of the lungs, is called "negative pressure;" a pressure which is larger in proportion to the amount of stretching imposed upon lung tissue by inspiration. When abnormal conditions exist, as in asthma, spasm of the glottis or diphtheria with membrane, or even when the glottis is closed during forcible expiration, as during the act of defecation, there is compression of air in the chest; in other words, the intrapulmonary pressure is increased. Intrathoracic pressure is also increased with expiration under such conditions and with the increase, pressure is exerted upon the large veins and other structures outside of the lungs in the thorax. Forcible inspiration lowers intrathoracic pressure whether the glottis is open or closed, because it creates a vacuum. With increased pressure, there is a change effected in the mediastinal space, *i.e.*, the large veins are partially blocked and eventually the coronary arteries are emptied. As the nutrition of the heart is dependent upon these arteries, it becomes a serious matter, because it interferes with their circulation. Children should therefore be taught to undergo physical strain without closing the glottis or catching or holding the breath (see Howell's Physiology).

The Circulatory System and Exercise.—The physiology of exercise in relation to the heart is discussd in the article on the heart (School Hygiene, p. 945). Its importance rests first upon its relation to the efficiency of the coronary arteries, and second, upon the reception and propulsion of blood from and to the great blood vessels connected with it and thence to every part of the body.

The large veins in the neck and axilla are under the pressure of an atmosphere, exerted through the skin, and the same is true of the inferior vena cava in the abdomen, but the inferior cava in the thorax, the superior cava and the right auricle are under a pressure less than one atmosphere. This difference in pressure acts as a constant favoring condition to the flow of blood to the heart. The difference is markedly increased at each inspiration, during which there is an increase in the velocity and volume of the flow to the heart; blood being sucked from the extrathoracic into the intrathoracic veins. So far as the inferior vena cava is concerned, this effect is augmented by the simultaneous increase in abdominal pressure, for as the diaphragm descends it raises the pressure in the abdomen, while at the same time it lowers the pressure in the thorax. The two factors coöperate in forcing more blood from the abdominal to the thoracic portion of the cava.* The opposite effect probably does not occur in the arteries because they are thick walled, and are distended by a high internal pressure.

In the extremities, circulation is hastened by the friction of acting muscles on the veins which press the blood toward the heart. Experiments with the plethysmograph show that two tablespoonfuls of blood and lymph are forced out of the arm when it contracts. Muscular contraction in this way therefore saves the heart considerable work, and draws fresh blood to the part. Balance exercises are physiologically harmful on this account because they retain the muscles in one position too long.

The Neuromuscular System and Exercise.—As every sensory stimulus is followed by a motor reaction, it follows that the connection between the nervous and muscular systems is a very close one. In fact, the two together are often called the neuromuscular system.

Muscle tissue has two characteristics: irritability and contractility. Irritability is due not only to nerve stimuli but also to an inherent function of muscle tissue itself. Contractility is the result of such irritability. Stimuli from the central nervous system may come at a rate varying from 30 to 120 per second.* Contractility can in turn create new contractions in another coördinating group of muscles, if followed up at once by the stimuli which such contractions produce and send to the central nervous system. For example, the movement of one foot in walking prepares the way for the corresponding movement of the other foot.

There are two kinds of muscular actions: (1) Endurance exercises. (2) Efforts involving strength, skill, and speed.†

1. Endurance exercises are simple and habitual and are distributed over the large muscles. They are represented in marching, walking, ordinary running, hopping, dancing, swimming, rowing, skiing, bicycle riding, and mountain climbing. They require very little conscious effort except when fatigued. The total amount of work, however, is far greater than in exercises of strength, skill, or sudden excessive speed, and they are very much more effective than any amount of gymnasium work. In climbing a hill of 1000 m. in six hours, a 14 year old boy, weighing 51 kg. with clothing and equipment, would lift vertically 51,000 kg.-m. and horizontally, 3750 kg.-m. Total, 54,750 kg.-m.‡

After endurance exercises, the pulse drops at once to normal. The blood pressure and temperature, however, fall less rapidly. The circulation is increased in force and rapidity for some time, especially if followed by a bath. In practicing endurance exercises, rapidity of motion should be increased gradually for some time, until the ability to perform the exercises and the difficulty of the task are balanced.

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* Howell Physiology.

† Mackenzie, R. T., in "Practical Treatment," by Musser and Kelly, i, p. 334.

‡ Kruse and Selter, "Gesundheitspflege des Kindes."

Endurance exercises may last for an hour and should occur systematically every day (article on the "Heart," p. 945).

2. Muscular coördination is the greatest factor in muscular efficiency. It is defined by Bowen as energy which causes contraction and relaxation, or action and inhibition at the same time. Any ordinary useful motion involves one set of muscles which contracts to make the motion, another set which relaxes to allow it and a third, which contracts moderately to guide it. All useful motions are a series of orderly alternate contractions and relaxations. The elimination of useless movements is necessary for the production of control and economy of effort. Habits of skill are most essential, not only because they are valuable from the viewpoint of motion but also because they produce permanent "presence of mind" and mental alertness. From a physical point of view, it is probable that violent types of effort such as heavy lifting, strenuous forms of athletics, and excessive and sudden spurts of speed are injurious to the heart and blood vessels.

There is a *proper amount of exercise* which depends upon:

1. The physical condition as shown by the individual's ability to recover from exercise over night.

2. Energy requirements in other lines, either of growth, sickness, or other work.

Fatigue after Exercise.—Muscle will be found to do the greatest amount of work with somewhat more than half it can lift. If a muscle is trained, fatigue following strain will be delayed. If concentration is required to produce skillful movements, fatigue will appear more rapidly. Up to a certain point of fatigue, physical exercise is largely a constructive process, and some fatigue is necessary to nervous development. If the intervals between successive stimulations of a muscle are several seconds in length, recovery is practically complete between each one. If, however, they follow each other too rapidly or if the stimulus be too great, exhaustion and stiffness occur. Exercise may produce acute constitutional exhaustion shown in breathlessness, dizziness, and mental anxiety, due to acute inadequate elimination of CO_2. Recovery, however, is rapid. Exercise may also produce fatigue of the whole muscular system from which rest of a day or two is necessary. It may produce acute dilatation of the heart, or a chronic, nervous fatigue called "Staleness," from which recovery may occur only after weeks or months (R. T. Mackenzie).*

Muscular Strain.—This follows effort which is too vigorous. Sometimes the connective tissue is torn or the protoplasm crushed. In the biceps muscle which in the average adult contracts with a force of one thousand pounds, and in proportionate measure in the child, great pressure is exerted on the fibers, sometimes producing soreness. This may be avoided by gradually working up to exercise and by treating at once with hot applications and massage.

The Thermal System and Exercise.—Muscular exercise draws the blood to the muscles and to the covering skin. This in turn reacts upon the heat center, thus increasing the temperature. After exercise has continued for a short time, the temperature rises to 100 degrees. The performer is "warming up" and can work with an added degree of ease. The greatest amount of heat is produced when the antagonistic muscles are exactly balanced and no motion results.

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* Musser and Kelly, "Practical Treatment," i, p. 355.

"Taking Cold" after Exercise.—When gymnastics are made a habit, the blood vessels of the skin are kept in ready response, so that the first hot days in spring are not so relaxing and there is much less danger of taking cold any time after exposure when the skin blood vessels are dilated. If after violent exercise, when the temperature is raised above normal, there is sudden cessation of activity, heat production is suddenly stopped. If the clothing is not free from perspiration, evaporation continues thus reducing the temperature to a point considerably below normal. This produces chilliness and predisposes to colds. Therefore, after very active exercises, a bath of gradually decreasing temperature should be taken and clothing should be changed.

The Digestive System and Exercise.—One of the greatest benefits of exercise is increase of appetite. Mental work interferes with digestion more than physical unless it be swimming in water at 70 degrees or below. Muscle fatigue alone probably does not interfere with digestion. Investigations of dumb-bell exercises practised between one and two o'clock in the afternoon showed that no ill effects resulted so soon after eating. Too heavy a meal, however, may affect the heart and breathing by pressing the stomach against the diaphragm. It is thought that 15 to 20 per cent. of the food taken can be utilized for work. In the case of bicycle riders, 40 to 45 per cent. can be used for work. Some sugar is good for children who exercise freely.

PLAY

Play is the joyous, spontaneous expression of self-activity. Through it, Nature produces both growth and development. It utilizes instinct and the sensory organs, trains the higher mental processes through curiosity, which it both stimulates and satisfies, and thus brings the child into close organic touch with his environment. As a matter of fact, it is difficult to draw the line between work and play. For the child, work may be play and play may be work, the difference lying in freedom of activity and in a purpose which is emotionally happy.

There are four theories of play. The evolution theory of G. Stanley Hall, since it has a biological basis, is the generally accepted one. He regards play "As the motor habits and spirit of the past of the race, persisting in the present as rudimentary functions akin to rudimentary organs."*

Play may be divided into the following groups: free play, organized play, games and athletics.

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* Wood, Walter, "Children's Play and Its Place in Education."

Free Play.—Until the age of six years all play, unless it be related to Kindergarten activity, is informal and free. It is essential to avoid precocity in play, maintaining the early simple types as long as possible. As intelligence and coördination develop, games are introduced with increasingly difficult situations and rules, until finally the timid and solitary play of very early childhood is replaced by organized gregarious effort toward or against an understood end. In the meantime, habits of courtesy, consideration, humility, justice, cheerfulness, self-control, hardihood, purpose, system, daring, and honesty, the power to carry things through, and the loyalty and self sacrifice that expresses itself in later childhood in the playing of team games are being developed.

Games which are much more formal have positive educational influence. "Children who are slow and dull and lethargic, who observe but little of what goes on around them, who react slowly to external stimuli, may be transformed by games. Perceptions are aroused. The timid child learns to take his turn with others; the bold, selfish child learns that he may not monopolize opportunities; the unappreciated child gains self-respect and the respect of others through some particular skill. He learns to take defeat without discouragement, and to win without undue elation. Growth in power of will is seen in initiation, in courage to give "dares" and to take risks, in determination to catch an opponent, to make a goal or to win a game. Due to rules of the game, it is the best training in inhibition. Relaying must be in turn. Players must not stand over the line until the signal is given; aiming with the ball must be deliberate and careful instead of hap-hazard, etc."*

Organized play, which should begin in the Kindergarten, has a remarkable effect upon juvenile delinquents. Public sentiment of the team brooks neither delay, indecision, laziness, nor carelessness and is the spur that places many a delinquent boy on his feet. In some districts situated near small parks delinquency has been reduced 28 per cent. by play.

Each period of childhood shows definite play characteristics.

(With this subject, compare "Physical and Mental Characteristics," p. 982.)

Birth to one and one-half years:

Sight (bright objects); hearing (rattles, large spoons and tin dishes, clocks, etc.); feeling (rubber animals, balls, spools, paper, etc.); muscular activity (objects to be reached) hands, feet, rhythmic kicking, etc.

One and one-half to four years:

Running (stones and balls to throw and kick); climbing (ladder, chairs); swinging (seat swing, perambulators); pushing, dragging, and pulling (carts, hobby horse); constructing (blocks, sand pile, nests of boxes, Hailmann's beads, peg boards); digging (sand shovels); imitation and imaginative play (dolls, toy animals, furniture); rhythm (swings, songs, finger plays); sense play (discrimination of qualities of objects) (wet, dry, round, straight, strong, weak, etc.; Montessori materials for sensory development, fabrics, utensils, and dishes, soap bubbles, etc.).

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* Bancroft, "Games."

Four to six years—Kindergarten period:

Physical activity.* Marching does not give the freedom of movement and vigorous exercise which little children need. Little children need to walk, run, skip, hop, clap their hands, swing their arms, and whirl about, and they need space for these spontaneous movements. Four year old children cannot control themselves enough to hold hands while swiftly moving, and they should not try to play in groups of more than ten, as a larger number involves too much self inhibition and social excitement. It is very difficult for many children of this age to enter into physical activities with other children. Such children should not be forced. At the age of five and a half to six, children can skip together and change partners. The ladder, tricycle, jumping hole, tops, and elevated rail are all good for balance. For imitation and imagination (dolls, doll houses, and equipment, balls, bean bags, Noah's ark, engine and train, wheel barrows, etc.); for construction (sand piles, shovels, corn cobs, scissors, paper, paste, large weaving materials, stringing materials, etc.):† for rhythm (songs, stories, rhythmic games such as "counting out" nonsense rhymes, etc.); sense discrimination (note three degrees in quality, *i.e.*, hardness: bedstead, hair mattress, feather pillow, etc.). The teachers of the latter years of the Kindergarten and the first years of the Primary find story plays very useful. Music should not be used till rhythm is learned without it.‡

Seven to nine years—physical activity:

Individual or social competitive plays (balls, see-saws, poles, swings, climbing ropes and ladders, bows and arrows, dolls, ring toss, jumping rope, roller skates, etc.); for construction (carpenter's tools, building materials, sewing materials, cloth bead looms, raffia, clay); for collecting (stamp books, insect nets). Dramatic play: house and store, Indians, out-of-door activities or any activity with which the children are familiar. Rhythm: music, singing, and rhythmic games and folk dancing. Nature: caves, shacks, tents, gardening, pits, exploring, etc. Curiosity: magnet, magic lantern, puzzles, etc.

Ten to twelve years:

For the most part boys and girls should play separately at this age.

Skilled competition: athletic apparatus, baseball, skiing, wrestling, stilts, jumping rope, jackstones, bean bags, pillow dex, crokinole, sleds, skates, kites.

Exploring: row boats, sail boats, skates, tobogganing, tents, etc.

Constructing: tools for making large play apparatus, sloyd, meccano, basketry, elaborate doll's wardrobe, bead work, knitting.

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* Temple, Alice, "Survey of Kindergartens of Richmond, Indiana."

† See Palmer, Luella, "Play of the First Eight Years."

‡ See Physical Training for the City Schools of Michigan, Published by the State Superintendent of Public Instruction, Bulletin No. 2 (1914).

Thirteen to fifteen years:

Athletics (for boys), soccer foot ball, basket ball, tennis, hockey, volley ball, indoor baseball, are all favorite physical activities; (for girls), tennis, hockey, and basket ball *with care*, folk and gymnastic dancing, and rhythm work of all kinds. All of these games hold an element of danger unless they are properly supervised.

The choice of games therefore should depend upon previous training or experience and conditions of fatigue. If children manage their own games, they will not play when tired. If rhythm enters into exercise, the muscles are more likely to be relaxed, and fatigue postponed. If fun and laughter prevail, nervous strain vanishes. Children on the play ground too often walk around aimlessly. It is, therefore, a great advantage to have a playground instructor in charge of the recess periods. Five minutes in the classroom with open windows and lively competition in games is obviously worth more than listless exercises out of doors for a much longer period.

Athletics.—The choice of ahtletics requires much greater care, and a conscientious medical examination should be given before engaging in any form. In any doubtful case, it is desirable for the school physician or the gymnasium director to get in touch with the student's personal physician. Visits of local physicians to the gymnasium are to be encouraged so that better coöperation and understanding may be secured.

Basket ball, allowing no periods of rest, demands the most constant activity. Of all forms of athletics it is the greatest strain on the heart. The pulse should come down to 100 after five minutes rest following the game, and no person not organically sound nor muscularly fit should attempt it. The same is true of hockey, another game requiring great activity. Girls should not be allowed to work at all during the first three days or more of the menstrual period Girls who are low in vitality, in whom the menstrual function is either not established or painful, and post-operative cases should be debarred from athletics. For this type the work should be in the corrective class, and much of the period should be spent in the recumbent position on floor mats.* The volume of the heart in children is proportionally smaller to the diameter of the arteries than it is later on. During adolescence, the volume of the heart is increased twelve fold while the diameter of the arteries is increased only three fold (Benke). The child's growth is in relation to and dependent upon the rapid development of the heart and its power to produce increased pressure of blood in the arteries. This ability increases with age but there is always danger of overfatigue in young and growing children. Rubner, the physiologist, and Kraus† condemn in no uncertain terms the whole competition idea in sport, forbidding races of one quarter of a mile to one mile among school boys.*

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* Shepard, Dr. Marion, Individual Prescription Work at Smith College, American Physical Education Review, xxii, No. 6 (June, 1917).

† Rubner, M., and Kraus, F., Gutachten der Königlichten Wissenschaftlichkeit Deputation für das Medicinal wesen vom Feb. 11, 1914, Betreffend Sportliche Uebungen von Schülern, Vrtjsdhr. f. gerechtl. Med., xlviii (1914), p. 304.

Mackenzie cites C. Rivieri † who reports a walking expedition lasting one week taken by 40 healthy boys. The boys ranged from 7 to 14 years of age. Expeditions of five to seven miles were taken daily including one 400-foot climb. On two days the larger boys walked 12 miles. Foot ball and other games were interspersed. Five days after their return, 20 out of the 33 showed cardiac enlargement of various grades. After two, four, six, and ten weeks, only a few hearts had returned to normal; and ten of them—nearly all younger boys—still remained appreciably dilated two and one-half months after the excursion. The author believes that such hearts would require one to two years to recover their normal condition.‡

An Extract from the Annual Report of the Surgeon General of the United States Navy, 1911, himself a "crack" athlete, makes the following statement: "The prolonged rigorous course of physical exercises necessary to excellence in physical sports is believed to be dangerous in its after effects upon those who indulge in athletic sports sufficiently to excel therein.

"When, under the conditions of service at sea, it becomes impossible to continue rigorous exercise, the individual easily falls prey to degenerative changes, tends to become obese, to lose physical stamina, and in the end he fails to render as many years of efficient service under service conditions as does his less athletic, but symmetrically developed, classmate.

"Recently the medical records of 625 former athletes of the classes of 1891 to 1911 have been examined to determine the bearing of early overtraining upon physical efficiency in after life—9 have died and 12 have retired.

"Of these 21 casualties, six have been due to tuberculosis, eight to mental or nervous diseases (three suicide on account of ill health), two indirectly to alcoholism, one death each to acute dilation of the heart and valvular disease of the heart, both directly attributable to track and crew racing, and 1 to an injury received in a football contest. Of the remaining 604 in the service, 198 have disabilities or abnormal conditions of sufficient moment to be of official record, and to which their record as athletes bears a possible or probable causative relation, and while not in most instances physically incapacitating the individual, tends toward an imminent or premature loss of service.

"Of these 198, 48 are referable to the heart or blood-vessels, such as arteriosclerosis, organic heart disease, heart murmurs, irregular or rapid heart action and hypertrophied or dilated hearts. The joints or motor apparatus are involved in 16 and the kidneys in 11 cases, 17 are either frankly tuberculous or have had symptoms indicative of tuberculosis. Neurasthenia, associated with gastric complications in several instances, occurred in 16 cases. The presence of 25 cases of appendicitis and 15 of hernia in this series is of interest, especially in the case of the latter disability which appears to be associated particularly with a football record.

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* McKenzie, R. Tait, "Exercise in Education and Medicine."

† British Med. Journal (Sept., 1909).

‡ See Luby, Athletics and their Relation to War, Abstract from U. S. Naval Medical Bulletin, Jour. A. M. A. (Dec. 7, 1918), p. 1941.

"The opinion that long distance crew or foot racing is not beneficial but productive of serious harm, is one not held alone by the naval medical officer, but by those in civil life best qualified to judge, and it is believed that it needs but a decided stand on the part of an institution of the standing of Annapolis for the adoption of a "safe and sane" standard in these and other endurance contests to initiate a similar movement in the athletic world, making success dependent more upon skill and less upon brute force."

This conclusion is of more than ordinary value, as the Government requires a daily record of the health of every man thus, making it possible to eliminate other causative factors of disability. When all this has been said, however, it must be recognized that there is a moral element which makes team games desirable. Interscholastic meets have replaced the gang and done away with personal dishonesties, neighborhood jealousies, and race prejudices. If the physical harm of interscholastic meets can be controlled by proper supervision, they may have a great value. They are, however, generally undesirable for girls from a physical point of view. On the other hand, under conditions of social isolation they are difficult to surpass as a means of development.

Swimming is the best sport for bringing all the fundamental muscle groups into vigorous and harmonious activity, because the body meets resistance at every point, but ordinarily it should not last more than 20 minutes and should be followed by a good rub and a vigorous reaction. The best time for instruction in swimming is between the ages of 8 and 12. Swimming should be avoided by nervous children with a sensitive skin, by epileptics, choreics, and paralytics, by those with heart and lung affections, and those recovering from acute diseases.* See paragraph on Swimming Pools.

Rowing is excellent sport for children, except for girls at the menstrual period. It strengthens the arm and back muscles, and if there is a board in the bottom of the boat against which the feet can be braced, it is also excellent for the leg muscles. In both swimming and rowing, the number of breaths per minute is increased eleven to thirteen-fold, as compared with resting. Dr. Sargent of Harvard maintains that crew rowing is too strenuous an exercise for boys and girls under the college age.

Social dancing belongs to the group of mating plays. It is attractive to girls on account of the rhythm, but rhythm, *per se*, is a matter of indifference to boys and men. Forbush says, "Dancing partners have the advantage of vigorous exercise and lively companionship, but in their ordinary form, they have the disadvantage of late hours and artificial ambitions." Enebuske says, "Gymnastic dances are rhythmical. The movements must be those which, by previous training, have already become nearly automatic. It is only through this mindfulness that they can meet the requirements of the esthetical perceptions and to those same esthetical perceptions is the music applied. The music, therefore, assists on the physical side in bringing about volitional passivity." (It may be questioned from a moral viewpoint whether passivity of the will is desirable, especially in the prepubertal and adolescent periods.) Bowen says, "Young boys and girls in dancing school, learning to ape the manners and play habits of ladies and gentlemen of marriageable age, at a period when nature has intended them to play tag games and climb trees, proves the ignorance of their parents. The formation of fraternities and social sororities by young people of the high school, instead of ball teams, and the cultivation of social dancing in place of out-door sports, proves the lack of opportunity and encouragement for the kind of play their stage of development demands." Forbush ("Play") advocates Greek individual dances which develop grace and beauty with physical contact reduced to a minimum. The Eurrhythmics of Dalcroze, which are worked out with the same idea, have the added value of supreme mental concentration.

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*Eulenberg, Bach U., "Schulgesund-heits Lehre."

Folk dancing portrays "the indestructible fresh good temper and hardiness of nature that form constituents of the old Swedish folk character" (Enebuske.) Some, like the Highland Fling, can be danced on the sward; others require a floor. Most of them are too vigorous to be suggestive, and usually girls dance with each other. (Curtis, "The Practical Conduct of Play.")*

Bicycle riding develops coördination, increases the action of heart and lungs, and provides a change of environment. Hard, rapid riding may produce dilatation of the heart.

The winter sports, skating, skiing, tobogganning, etc., are most invigorating because they are free and energetic, and use the fundamental muscles. The cold air stimulates the appetite, the circulation is quickened, and constructive tissue repair is increased.

After school physical education activities are coming into prominence in many private schools of this country. They are a substitute for the home work requirements of early American life, and have the merit at least of keeping children off the streets and giving them constructive training. The importance of this may be seen in Johnson's "Survey of the Recreational Life of Cleveland School Children." On June 23, 1912, an investigation was made of the activities of 14,683 children, and it was found that under the age of 15, 41 per cent. were seen doing nothing, or "just fooling, *viz.*, fighting, teasing, pitching pennies, shooting craps, stealing apples, 'roughing a peddler,' chasing chickens, etc.;" 51 per cent. of all the children were in the streets. Seven thousand, three hundred and fifty-eight were playing legitimately, and 354 were working. An excellent article on the subject by William A. Stecher may be found in the American Physical Educational Review, October, 1917, xxii, No. 7, p. 40.

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*See Miss Burchenal's or C. W. Crampton's books.

TABLE 36.—STECHER'S TABLE OF EVENTS FOR AFTER SCHOOL WORK

Events		Years							
		8	9	10	11	12	13	14	15
Standing broad jump (In feet and inches)	Girls......	3.0 (4.4)	3.1 (4.6)	3.3 (4.9)	3.6 (5.0)	3.8 (5.3)	3.1 (5.6)	4.0 (6.0)	4.1 (6.0)
	Boys......	3.4 (4.4)	3.8 (4.1)	4.0 (5.4)	4.3 (5.1)	4.6 (6.3)	4.9 (6.6)	5.2 (6.1)	5.5 (7.4)
Running broad jump (In feet and inches)	Girls......	5.5 (6.0)	5.6 (6.2)	5.1 (6.8)	6.6 (7.8)	7.2 (8.4)	8.0 (9.0)	9.0 (10.8)	9.0 (11.8)
	Boys......	6.0 (6.9)	6.6 (7.0)	7.0 (7.6)	8.3 (9.1)	9.6 (10.8)	11.4 (12.2)	12.6 (13.5)	13.5 (14.7)
Triple standing broad jump (In feet and inches)	Girls......	10.4 (12.0)	10.6 (12.6)	10.1 (14.2)	12.1 (14.8)	12.5 (15.8)	12.9 (17.0)	13.0 (17.0)	13.1 (17.7)
	Boys......	12.0 (14.3)	12.3 (14.8)	13.0 (15.9)	14.0 (16.9)	14.6 (18.7)	15.1 (19.0)	16.4 (20.7)	18.1 (22.4)
Running hop, step, and jump (In feet and inches)	Girls...... 10-ft. start	9.2 (11.0)	11.6 (13.9)	13.8 (17.0)	14.6 (18.8)	15.5 (21.4)	15.6 (21.0)	16.4 (21.2)	16.6 (20.0)
	Boys...... unlimited race	10.0 (10 6)	13.0 (15.5)	16.4 (20.5)	18.0 (23.0)	18.8 (24.5)	19.9 (26.0)	21.7 (29.0)	23.0 (29.5)
Running high jump (In feet and inches)	Girls......	2.2 (2.6)	2.5 (2.8)	2.8 (2.1)	2.9 (3.0)	2.1 (3.2)	3.2 (3.3)	2.11 (3.1)	2.9 (2.1)
	Boys......	2.2 (2.8)	2.5 (2.1)	2.8 (3.2)	2.11 (3.4)	3.1 (3.6)	3.4 (3.9)	3.6 (4.2)	3.9 (4.5)
Basket ball far throw (In feet and inches)	Girls......	12.2 (17.0)	13.8 (20.0)	15.5 (25 0)	17.7 (28.0)	19.4 (31.0)	21.3 (35.0)	22.2 (35.0)	23.4 (36.0)
	Boys......	14.4 (19.0)	16.2 (22.0)	18.2 (26.0)	20.3 (30.0)	23.3 (35.6)	24.1 (37.0)	26.7 (37.6)	29.1 (39.0)
Running 50 yards (In seconds and tenths)	Girls......	9.4 (9.0)	9.2 (8.8)	8.8 (8.4)	8.6 (8.2)	8.4 (8.0)	8.4 (8.0)	8.4 (7.8)	8.2 (9.6)
	Boys......	9.0 (8.8)	8.8 (8.6)	8.4 (8.2)	8.2 (8.0)	8.0 (7.6)	7.8 (7.6)	7.6 (7.2)	7.4 (7.0)
Running 100 yards (In seconds and tenths)	Girls......	19.2 (18.0)	18.6 (16.8)	17.2 (15.8)	15.8 (15.6)	16.6 (15.4)	16.4 (15.4)	16.2 (15.4)	16.2 (15.2)
	Boys......	19.2 (18.0)	18.6 (16.8)	17.2 (15.8)	16.2 (15.2)	15.4 (15.0)	15.0 (14.4)	14.2 (13.6)	13.4 (13.0)

Stecher gives a typical schedule of competitive events for after school physical education activities for the school year which includes:

dodge* ball or end ball, 50-yard run potato race, baseball far throw, standing broad jump, triple standing broad jump, Captain ball, 60-yard run, shuttle relay, running, hop, step, jump, indoor baseball, basket ball, far throw, dodge ball No. 2, 75-yard run, plain relay or shuttle relay, basket ball round arm, and running broad jump in order of occurrence during the five last grades of the elementary school. The same are used for both boys and girls. It would be safer to omit the broad jump and have only a 60-yard dash for girls.

For classification and description of games, see Forbush—"Play"—Bowen, "Games." Bancroft, "Games." G. E. Johnson, "Education through Plays and Games." "Physical Training for the Elementary and Secondary Schools of the State of New York," Albany, N. Y.

The best books for rhythm, songs, and games for little children are:

Bancroft, Jessie H., "Games for the Playground, School and Gymnasium."
Paulsson, Emilie, "Foreign Plays."
Music Course, Parts I and II.
Newell, W. W., "Games and Songs of American Children."
Newton, Marion B., "Games and Rhythm Exercises."
Gaynor, Jessie L., "Lilts and Lyrics." C. F. Summy and Co.
Neidlinger, "Small Songs for Small Singers." Schirmer.
Gaynor, Jessie L., "Songs of the Child World." J. Church and Co.
Hill, M. J. and P. S., "Song Stories for the Kindergarten."
Brown, Corinne, "One and Twenty Songs."
Poulsson, E., and Smith, Eleanor, " Songs of a Little Child's Day."
Crawford, Caroline, "Dramatic Games and Dances."
Burchenal, Elizabeth, "Folk Dances and Singing Games."

See the Bibliography of Luella Palmer in "Play of the First Eight Years."

Play Grounds.—Many of the larger cities of the United States and some of the cities of Europe have felt the need of setting apart small portions of land in congested residence quarters as play grounds for children. The play ground originated probably in connection with settlements. At least 95 per cent. of the play systems of this country, as well as many other good things having social value, have been started by private organizations; but eventually play grounds systems should be supported by the School Boards and City Councils. In rural communities, athletic, Boy Scout, Camp Fire Girl, and play ground organizations are developed and maintained by the County Superintendents of Schools, the Young Men's or Young Women's Christian Associations, normal schools, or altruistic private individuals. Today there is a Play Ground and Recreational Association of America with headquarters at 1 Madison Avenue, New York, extending its service through a Field Secretary to any organization in need of assistance in starting new play grounds.

The play ground should be nearly level, no railroad or street cars should be near, and it should be in the midst of a homogeneous population. In Gary and in Cleveland the schools provide both play grounds and one or more indoor gymnasia. Several schools in both of these systems have swimming pools.

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* Stecher, William A., "The Theory and Practice of Educational Gymnastics," Publisher, John Joseph McVey, Philadelphia.

All new schools should have as a minimum one block of ground* and more is desirable especially in the country where parents may participate occasionally in the activities. City play grounds have from 7 to 20 acres. The play space should be carefully arranged with two features in view: (1) safety, (2) compactness. Swings should be placed parallel and just inside the fence and should be fenced off to prevent the "other child" from being hit. Other apparatus and fixed equipment should be around the edges or in the corners. The central space should be for games such as indoor baseball, volley ball, tennis, etc. A straight running track and quoits can be placed at the side. Tether ball will fit into a corner. (For size and construction, see Curtis, "The Practical Conduct of Play.")

The Equipment.—Ordinary swings are popular, dangerous, and they encourage selfishness, but they are excellent as an advertising agency. The same may be said of teeters and merry-go-rounds. The giant stride is made with a central steel pole 20 feet high set in concrete, with dangling ropes or ladders attached to the top. It is so arranged that a child may grasp the lower end and in swinging around, may touch the ground only at 15 or 20 foot intervals. This is fairly good exercise. The best forms of equipment are wooden slides, toboggans, and the sliding pole. Much of this is made by W. R. Tothill and can be purchased of Marshall Field and Company, Chicago. The best play grounds, however, are without equipment, since it distracts children from organized games.

For proper distribution as to age, children may be divided into three groups. First, up to the age of seven.† Second, elementary school children, the "Big Junior Age." Third, the high school or adolescent period. If there can be enough directors, there should be six divisions, one group for both boys and girls to the age of seven, one for boys and one for girls from seven or eight to thirteen, one for boys and one for girls of adolescent age and one for adults. There should be no more divisions than directors.

There should be separate yards for boys and girls. If boys and girls are kept constructively busy, however, they may play together, especially if parents are frequent visitors. Care is required in the use of such apparatus as swings and no opportunity should be given for loafing.

Children under the age of six should not be taken to a general play ground but to quiet, shady places which are provided with seats for mothers, with sand piles, hammock chair swings, low balance rails, low teeters, short slides, and a wading pool. They need considerable freedom but should be constantly watched and guarded, somewhat as they are in the ordinary kindergarten. The sand pile is a great favorite with little children. Sand bins need no floor if the ground is solid and dry. A low rail around the outside of the bin is desirable and the sand should be changed every month or six weeks. The best sand comes from the ocean but very good sand can be procured from plasterers* (p. 1060).

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* Curtis, H. S., The Reorganized School Play Ground, U. S. Bureau of Education, Bulletin No. 40 (1913).

† See " Play Grounds for Little Children."

If the play is vigorous, the length of the period is preferably short, and when the weather is hot, it is better placed late in the afternoon. Vigorous and quiet play should alternate. Children of the first five grades in the Gary schools have two hours of play daily, of the sixth to the eleventh grades, one hour daily.

The most important feature of the play ground is the Supervisor. He draws the crowd; he demolishes the "gang" and creates the "team;" he organizes play activities so that the development of children is progressive; he teaches coördination, good sportsmanship and is himself a subject for hero worship. In 1913, Cleveland had 36 open play grounds half of which had apparatus. Of 1869 children seen within a radius of four blocks of these grounds, only 11 per cent. were in the play grounds. In 1915, 6488 played in the play grounds in one day. This increased attendance was due to the activity of play ground Supervisors who had organized the work and furnished the inspiration. In many places teachers are becoming play leaders after school hours.†

If it is a fact that the movies seem to be superseding the settlements in attendance, that mothers are more and more called into industry so that homes are without guidance, and that schools for religious instruction are deserted, it is all the more important that teachers and play ground directors provide the type of leadership that will inspire and control young citizens upon whom the nation must depend.

Gymnastics.—The Swedish system of gymnastics, which is the result of nearly 80 years of development, is the basis of all gymnastic work. School work results in temporary passive congestion of the brain and abdominal organs, decreased respiration, lowered muscular control, and mental fatigue.‡ For the relief of these conditions, a definite order of exercises has been developed which are proportionately more difficult as efficiency progresses.

This relief is brought about first by the mechanical effect of exercise on the body.§ Among the mechanical factors, we may regard as important the contraction and relaxation of muscles, the movements of joints, the increase of venous, nervous and lymphatic circulation, thoracic activity and the more vigorous action of peristalsis and glandular organs induced by a greater variation of intra-abdominal pressure consequent on the more extensive action of the diaphragm and abdominal muscles and the shaking and massage of the abdominal organs. Second, by the adjusting influence of the central and sympathetic nervous system in response to direct or reflex stimulation by the products of muscular activity. Third, by training of subjective motor control, in other words, the muscle sense. (Objective motor control is better acquired through plays and games.)

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* Palmer, Luella, "Play of the First Eight Years."

† Johnson, G. E., "Education through Recreation."

‡ Enebuske, "Progressive Gymnastic Day's Orders."

§ "Physiology of Exercise."

The bases of Ling's system (Swedish) are:*

1. Introductory or order movements as marching and evolutions. These demand constant attention and connect the mental activity of the academic work of the classroom with the physical exercise of the gymnasium.

2. Leg and arm movements (knee bendings, lungs). These draw the blood in larger quantities toward the extremities, relieving the strain and the oppressed organs. Exercises for broken arches, such as heel raising and toe raising, belong here.

3. Arching movements, in which the chest is bowed backward and drawn upward to its fullest capacity often by the help of apparatus. Increase of the lumbar curve must be avoided here. Heaving movements, in which the body is drawn upward by the arms while it is suspended. Both of these movements expand the chest and induce more energetic respiration.

4. Balance movements: these demand equilibrium in difficult situations, quiet the rapidity of the heart, and diminish the previously raised blood pressure.

5. Shoulder blade movements correct anterior, posterior, and lateral curvatures of the spine, especially of the upper thorax, by vigorous and sustained contraction of the scapular depressors and abductors.

6. Abdominal exercises strengthen the abdominal wall, increase the mobility of the spine, and stimulate the abdominal organs by alternate increase and decrease of the abdominal pressure. They consist of knee bendings and trunk raising from the lying position.

7. Lateral trunk movements produce the same effect as the abdominal or back movements. They involve the waist and loin muscles particularly. The portal and general abdominal circulation is stimulated. These movements are especially beneficial in constipation.

8. Slow leg movements diminish the blood pressure and heart beat which have been increased by the other movements.

9. Jumping and vaulting: these are advanced balance and subjective motor movements of the body as a whole. In jumping, the legs alone are used. In vaulting, the arms are used to support the body while the jump is made.

Systematic running, which is the climax of the lesson, is the best of all exercises to improve the mind, to strengthen the heart and respiratory organs, and to increase the power of perfect and prompt adjustment of the whole circulatory system to varying degrees of activity. It is the conditioning factor and index of endurance, vitality, and general condition. Marching is at the rate of 115 steps per minute. Running, at 165 steps per minute.

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* "Posse-Kinesiology."

These movements represent all or special features of leg, back, abdomen, lateral trunk and arm support exercises. They demand great coördination, well timed muscular effort with judgment of height, distance and bodily momentum.

10. Respiratory exercises at the end of "the day's order" are characterized by deep, measured breathing which causes a more powerful suction on the vena cava, reduction of the blood pressure without the preliminary rise that always occurs when violent exercise suddenly ceases, mobility of the chest, the free flow of lymph and blood in ordinarily unused portions of the lungs, straightening of the spine, strengthening of the inspiratory muscles, and descent of the diaphragm, which causes greater variations in intra-abdominal organs (Skärstrom). With this, the day's order is at an end.

The "day's order" is the characteristic of Swedish gymnastics. If given properly, every exercise is taught with a view to posture. For example, if arch flexions increase the lumbar curve, compensatory abdominal movements are made to follow immediately. No position should be used as the commencing position of a movement unless it has previously been practised as a final position of some other movement.

Apparatus of two kinds may be used:

1. Stationary, as ladders.
2. Calisthenic, as dumb-bells.

The stationary pieces of apparatus used by the Swedes are: (1) The boom, (2) Swedish box, (3) ladder, (4) rope, (5) stall bars.

The pieces of Swedish apparatus are few, but are used very frequently.

The German system of gymnastics differs from the Swedish in its military character, its greater variety of exercises, and in the frequent use of apparatus. It is more akin to play than the Swedish type, and teachers are allowed greater latitude in the choice of exercises.

For corrective and remedial exercises, see: Lovett, "Scoliosis." Thorndike, "Orthopedic Surgery."

Bathing.—Practically all physical educators advise baths after exercise.

Effects of bathing after exercise (all bathing regardless of temperature):

1. Stimulates circulation. It is especially good after exercise as it keeps up the stimulation of the heart and prevents blood pressure from dropping quickly ("Physiology of Exercise").
2. It removes perspiration and prevents taking cold.
3. Cleanses (hot or warm bath best).

Baths are classified according to temperatures as:

1. Cold bath in which the water is colder than the room, 70 degrees.
2. Cool bath in which the water is between the room and body temperature.
3. Warm bath in which the water is the same as body temperature or 6 degrees either way, 92 to 104 degrees.

4. Hot bath in which the water is 110 degrees or higher.

1. Cold baths are the most stimulating and therefore best for sluggish people. They prevent taking cold if the body is overheated, and they prevent a rapid fall of blood pressure after violent exercise. Body temperature must not be too much reduced, however, as occurs sometimes in the case of long distance swimmers. Records, for this reason, are held by fat people rather than by the best swimmers. After cold bathing, there should be vigorous rubbing and drying. Cold baths should never be taken by thin or nervous people.

2. Cool baths. Very nervous people get the same effect from a cool bath that phlegmatic people get from a cold one.

3. Warm baths should be taken in a cool room and then, in winter, not oftener than twice a week.* They should be used for cleansing purposes only, and should last as short a time as possible. Too frequent bathing may produce acne, intolerable itching of the skin, and exhaustion. Winter itch is in many cases due to the liberal use of soap.

4. Hot baths should only be used locally for strains and bruises following exercise, and to break up an oncoming cold.

Different methods of taking baths:

1. Shower.
2. Tub, or plunge.
3. Sponge.

1. The shower bath is the greatest stimulant to the heart. It feels colder than a plunge bath of the same temperature. It should begin at a temperature of 90 degrees and remain there or gradually decrease to a temperature of 60°F. This is the ideal type of bathing for school children, as it is economical in both heat and time. An entire class or division can be bathed in a short time if accommodations are ordinarily good.

2. A cold tub bath is too great a shock for the majority of children.

3. A sponge bath is much milder in its effects than a shower bath of the same temperature, and it is an excellent bath for cleansing purposes. It is probable that except for cleansing of the skin twice a week, air baths at room temperature, followed by vigorous rubbing, would be more beneficial than water baths. (See article on "Swimming Pools," p. 1113.)

CLOTHING

Underwear which comes next to the skin should be of coarse mesh so as to allow the air to come in contact with the skin as much as possible and should be of easily washable material.

The *shoulder straps* of underwear or waists should be so arranged as to come close to the neck instead of near the shoulder tip.

The *hose supporter* is frequently a factor in producing round shoulders. The American Posture League is introducing a supporter which shifts the support to the big pelvic bones at the hip, as it is worn outside of the pelvic bones and ilia (Fig. 259). It thus frees the chest and shoulders from all strain. It can be obtained from Barnum-Van Orden, 379 Fifth Avenue, New York City. Round garters if not too tight are not objectionable. They are greatly to be preferred to the ordinary "elastics" worn by children.

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* Ormsby, Oliver S.

Children should not wear **corsets** (Fig. 260). Hygienic children's *waists*, modeled after designs produced by the American Posture League, can be obtained, as can corsets for older girls. Ordinary corsets should not be worn until much later in life, if at all.

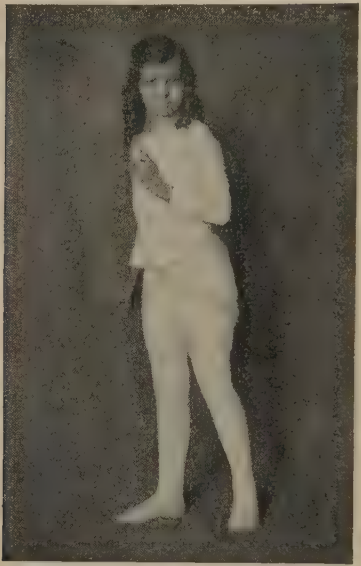

Fig. 259.—The Gymnasium hose supporter, approved by the American Posture League. (Barnum-Van Orden, N. Y. C.)

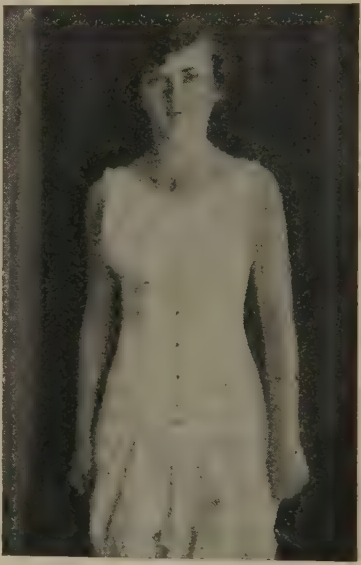

Fig. 260.—The Barnum-Van Orden corset endorsed by the American Posture League for correct outlines. (Barnum-Van Orden, N. Y. C.)

Dresses for the elementary school girl should be very simple. It is important to have the skirt made over a yoke or sewed to a skeleton waist which buttons on the shoulder so that it can be easily removed, provided that bloomers are worn under it. The material should be of light weight wool, or wash silk, preferably navy blue. The middy blouse is desirable because it is comfortable, easily washed and simple.

Boys' **coats** (Fig. 261) are frequently an aid to poor posture because they come too close to the neck in front and wrinkle in the back. These features have a tendency to produce round shoulders with the head and neck thrust forward.

Suits bearing the approval of the American Posture League can be obtained of the Snellenburg Clothing Company, Broad and Wallace Streets, Philadelphia.

Shoes: see article on feet.

SCHOOL ARCHITECTURE

Materials, types, units, foundations, basements, drainage and floors are discussed by Dresslar* in Munroe's Cyclopedia of Education. The school site should be chosen with respect to noise, safety from traffic, cleanliness, central location, and distance from high buildings. Direct sunlight should reach all instruction class rooms; it is, therefore, desirable to have the exposure for class rooms easterly, southerly, or westerly. The building should be in the form of an H or an E with a long axis. In large buildings the most desirable orientation is with the major axis running northeast and southwest. It is better if class rooms have the east and west exposures, assembly hall and accessories southerly and northerly exposures.

FIG. 261.

The class room is the unit, and should be 32 × 24 × 12½ feet in size, or less. No child should ever be farther from the teacher than 30 feet, both on account of seeing and hearing. The width of the class room should not be more than once and a half the height of the window on account of the light. The height should be not more than 12½ feet unless the horizon line is low; in that case it may be 13½ feet, but never higher.

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* Brainerd, Wm. H., Sanitary Conditions that Should Operate in Selecting a Proper Site for a City, Rural or Village School Building, Fourth Internat. Congress of School Hygiene, ii, p. 72; Rapeer, "Educational Hygiene," p. 333, etc. Dresslar, F. B., "Rural School Houses and Grounds," *ibid.*, pp. 38–41.

It is essential to have primary rooms as large as those for children of the higher grades. In some schools the room for Kindergarten children is larger. Desks are placed preferably so that the aisles are parallel with the long axis of the room. The first row should have little more than the width of an aisle between the desks and the outer or window wall, both because it brings the desks near the light and also because it gives a wider aisle on the opposite side near the blackboard.

The best *window shades* are translucent, adjustable from either the top or the bottom, or from the middle, and should not transmit colored rays. They can be supplemented by opaque shades between them and the window, to shut out direct sunlight, if necessary. Sash window curtains, while attractive, are undesirable, as they obscure the light.

Walls.—Class room walls are best made of hard plaster and decorated with oil paint so that the finish will be without gloss. Photometric tests show that the most satisfactory colors are light gray or buff. If the room is light, pale green may be used, but green and red absorb light. In poorly lighted rooms, shades of color corresponding with the color of the walls may be drawn over the blackboards when not in use; this increases the light one-half. The ceilings should be white or very light, and without gloss.

Blackboards.—Slate is the best material for blackboards, and can be obtained in either green or a strong black. The blackboard is an important addition to the schoolroom equipment, because it affords a desirable change of position for the pupils. It is better to use the entire front wall unless part of the space is taken by the dressing room door, the wall opposite the windows, and perhaps the rear wall, though this is less desirable. If it is placed on the window side of the room it will affect the eyes unfavorably. The front board may be from 5½ to 6½ feet high, the others 4 feet. In primary rooms the bottom of the boards should not be higher than 26 inches from the floor, in upper grades 30 inches from the floor. Hard, dustless chalk is preferable, and soft dustless erasers. Chalk troughs 2½ to 3 inches wide should be provided with a detachable wire screen of coarse mesh, through which the chalk dust may fall. This demands thorough cleaning at frequent intervals.

Floors.—On account of noise, ground air, and cold air, all the floors—unless there is fire-proof construction—require double flooring. There is seven degrees of difference between the temperature of the floor and that of the air 5 feet above the floor, so that the children suffer with cold feet unless this is minimized as much as possible. The floors should be made of rift or quarter sawed pine or hardwood and dressed with a mixture of boiling linseed oil and paraffin, so as to make the surface smooth and hard. Mastic insulite on concrete and battleship linoleum also make good floor surface.

The teacher's desk is no longer placed on a platform, as the latter is a trap for dirt, and the platform interferes with the movement of children about the room.

Schoolroom Desks, Basic Principles.—A movable seat and desk in one unit.

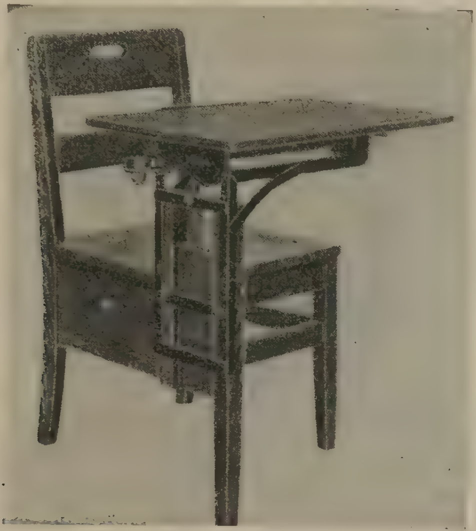

Fig. 262.—The Moulthrop desk. School Seating Langslow, Fowler Company, Rochester, New York.

"A seat modeled to the normal shape of the thighs and buttocks, allowing thereby the pelvis to rest on the tuber ischii, thus avoiding the forward slipping of the pelvis with its forward rim tilting upward and consequent distortion of the spine. This requires a concavity in the seat of $\frac{3}{8}$ inch.

"A seat shaped to give an adequate clearance for buttocks to allow the individual to hold his back erect.

"A seat shaped to give adequate clearance for knees to avoid pressure on nerves and blood vessels in back of knees.

"A seat adjustable to height, so that the thigh of the pupil when seated will be perfectly level, the lower leg being in an exactly vertical position with the foot resting wholly on the floor.

"A back so formed as to allow the occupant to maintain the torso in the normal erect position.

"A movable back support, convex forward, that will maintain the normal forward lumbar curve, and compel an erect position of the entire spine.

"A back of proper height with a top crossbar to prevent round shoulders.

"A desk that can be easily adjusted to any desired position, height or angle for drawing, reading or writing.

"A back, seat, and desk so correlated as to give a correct and yet comfortable "set up" to the occupant when at work. The proper correlation demands that the edge of the desk nearest the seated pupil shall touch the central part of his body without pressing against it.

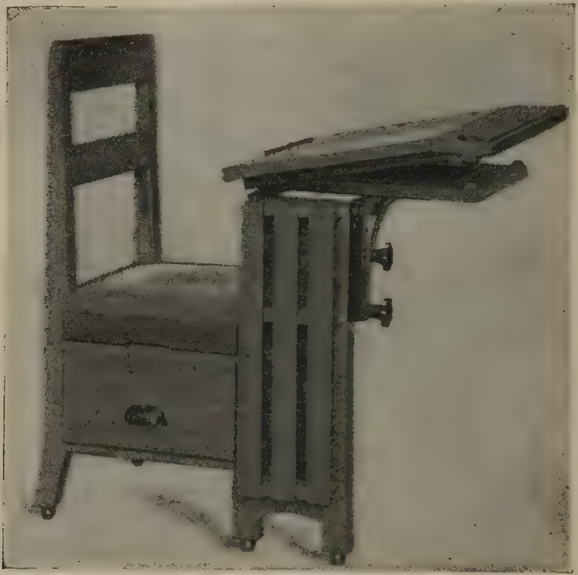

FIG. 263.—Moulthrop Desk.

NOTE.—This is technically described as "Minus distance," *i.e.*, such a relation between the rear edge of the desk top and front edge of the seat, as to bring the former a short distance over the latter. If the rear edge of the desk top is in such a relation to the front edge of the seat, so that a vertical line dropped from the rear edge of the desk top will coincide with a vertical line dropped from the front edge of the seat, it is called "zero distance." If there is a space between the above mentioned vertical lines, it is called "Plus distance."

"It shall be of such a height that the forearm shall be at right angles to the upper arm during writing. It is desirable to have a top that tilts and slides backward and forward, so that the top may be pushed back when the pupil is not using it."

The best models are the New York study chair (70 Fifth Ave., New York) and the Moulthrop desk (made by Langslow, Fowler Co., Rochester, N. Y.). The New York study chair is also provided with reclining back and foot extension so that it can be converted into a comfortable lounge during rest periods. The Mosher chair is the best for Kindergarten children.

Cloakrooms are usually 5 feet wide and as long as the front wall of the corresponding classroom, into which they open by a door. They are ventilated by means of openings in the lower part of the door, through which the exit air passes on its way to exit flues in the upper part of the opposite wall of the cloakroom. This keeps the clothing dry. It is important that hooks be sufficiently far apart, to keep the garments separate. There should be drip racks for wet umbrellas and foot racks for over-shoes. Many of the better schools provide hot and cold running water in every cloakroom. Cloakrooms will soon be obsolete. They will give way to ventilated metal lockers which can be placed in the corridors or built in their walls and provided with combination locks and keys.

Toilets.—This is one of the most difficult of all sanitary problems. In the largest city schools, well-lighted towers are built with separate ventilation and exhaust fans, so that the legal requirements of changing the air 12 times an hour, instead of six, can be met. This arrangement also affords greater privacy, and greater convenience. In other schools provision is made for toilets on each floor. In the majority of schools one toilet each, for boys and girls, is placed on each floor, with the others in the basement. The standardized number of toilets is one for each 15 girls and one for approximately each 25 boys. Urinals should also be provided, one to each 15 boys. It is desirable to have the toilet rooms lined to a height of 5 feet with the most impervious marble obtainable. Asphalt which is resistant to both water and acid makes a good floor, and should be pitched to a drain. Wood is used only for the doors and individual stalls. The stalls should be made of pressed steel, enameled (the Ariton is used in the Cleveland public schools). Thus equipped, the hose can be turned on freely so that cleanliness may be secured. Toilets require mopping each day, but disinfectants are undesirable. The fixtures can be kept clean with a weak solution of hydrochloric acid.

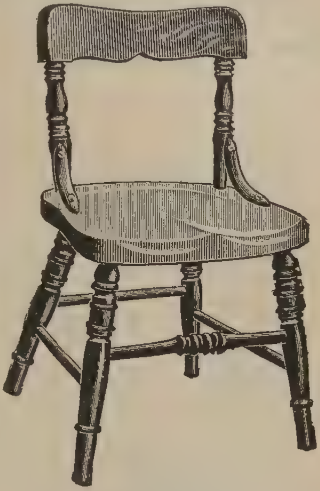

Fig. 264.—Mosher chair. The Mosher Hygienic Chair was designed by Dr. Eliza M. Mosher to meet a demand for a chair built on correct principles. It has a saddle seat and but one wide strip, for the back, allowing the hips and shoulder of the child to adjust themselves to a comfortable, upright position. The chairs are finished in forest green, and are made twelve and fourteen inches high. In ordering state the height wanted.

Toilets in country schools are a far greater problem on account of sanitary ignorance and laxness in the country, the necessity of placing them out of doors, the menace to health in large sections of the world from soil pollution and the danger of contamination to the water supply. In the plans for a model rural school at Kirksville, Missouri, arrangements are made for flush toilets on the first floor. This is possible because there is machinery in the basement which furnishes the power (Fig. 265). Frequently, such toilets are placed in the basement. A recently invented indoor toilet is the chemical closet (Fig. 267) which, by means of chemicals, destroys bacteria and odors. It is provided with a circulation of air and exhaust, so that no odors escape. Out-of-door toilets or privies should be placed somewhere between 50 and 150 feet from the school building, the toilets for boys and girls being entirely separated from each other, and hidden so far as possible by vines and evergreen bushes of some kind. It is better if there be but one seat to a stall; there are seldom more than two seats. These should have tight-fitting hinged covers that are kept down except when in use. The windows are preferably 7 feet above the ground and large enough to let in plenty of sunlight. They should be carefully screened.

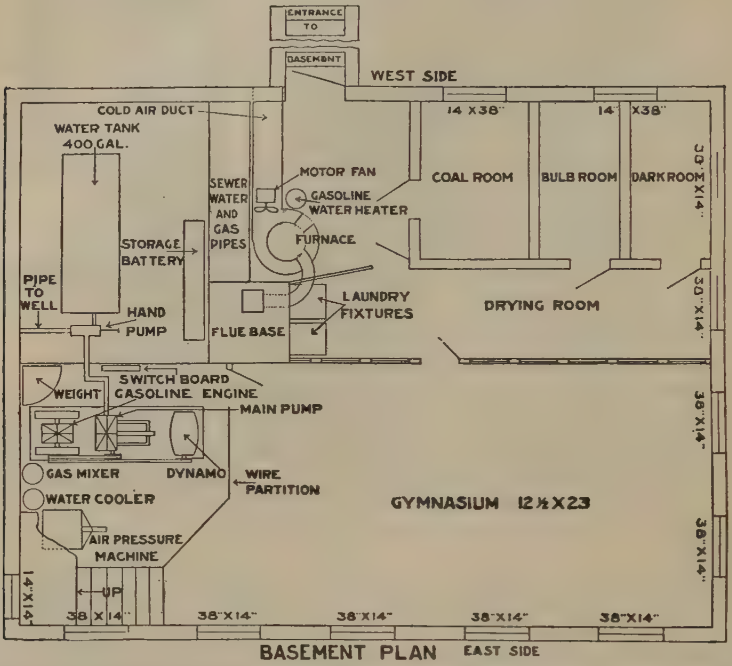

Fig. 265.—Model rural school. (From the Rural School Messenger, published by the First District Normal School, Kirksville, Mo.) Vol. v, No. 2, Oct., 1915.

There are three satisfactory types of out-door toilets: The dry vault, which may be provided with buckets, a box or a pit made of non-corrosive and non-absorbent material. This requires the use of pulverized dusty loam taken from dirt roads rather than sand, which is to be used freely. The second type is the septic tank constructed on the principle of a system of air-tight cells in which bacteria are destroyed by the decomposition and liquefaction of sewage. It is an excellent system. So far as possible such privies should be placed where the ground is sloping so that there may be better drainage. There is also an incinerating process.* Toilets should be inspected and cleaned daily.

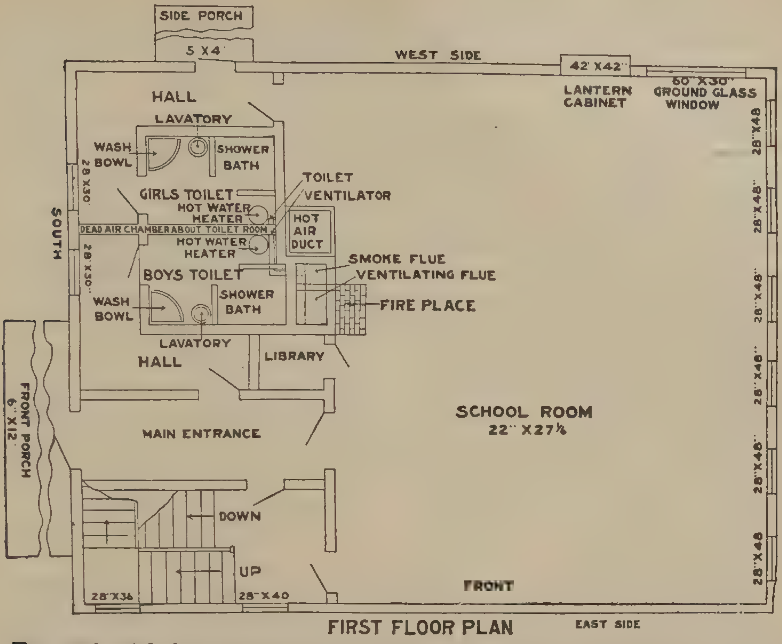

FIG. 266.—Model rural school. (From the Rural School Messenger, published by the First District Normal School, Kirksville, Mo.), Vol. v, No 2, Oct., 1915.

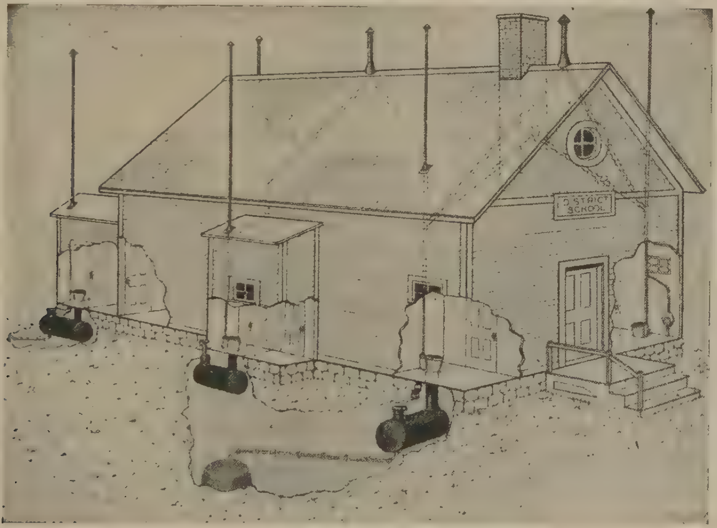

FIG. 267.—Indoor chemical closet.

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* Towner, W. T., Modern Methods of Sewage Disposal in Rural, Country and City Schools, Fourth International Congress of School Hygiene, ii, p. 48. Dresslar, F. B., Rural Schoolhouses and Grounds, U. S. Bureau of Education, Bulletin No. 12 (1914).

Dresslar, F. B., Rural School Houses and Grounds, U. S. Bureau of Education, Bulletin No. 12 (1914), whole No. 585.

It is important to place **washrooms** near the toilet rooms. They should be provided with warm water, children being taught to wash their hands after using the toilet. Equipment of washrooms to be adequate includes liquid soap in automatic containers, and paper towels. Children can be taught reasonable economy in the use of these towels.

Assembly rooms should be on the first floor. In the Skoki school at Hubbard Woods, Ill., the assembly room and kindergarten room can be thrown together.

Many modern schools are now equipped with special restrooms, emergency rooms, and playrooms—one for boys and one for girls. There should be other play space on the roof. Some schools have domestic science facilities with a housekeeping suite, to teach the care of the home, consisting of a hallway, kitchen, dining room, sleeping room, bathroom and living room furnished in accordance with the means of poor people. Some have shops equipped to teach sheet-metal work, carpentry, automobile repairs, pattern work, molding, wood working, printing and book-binding. Many schools have lunch rooms, physician's and nurse's office with space for a dispensary, and a dentist's office with equipment. Gymnasia and auditoriums are used for community center activities, and there are showers, swimming pools and libraries.*

Showers can be placed in the basement, if well lighted, ventilated and drained, or near the gymnasium. It is customary to install several showers in the same room with common arrangements for drainage. For older children each shower is placed in a stall, and there are separate dressing facilities. The floors are of cement or other impervious material, and the walls are damp proof. In elementary schools children are provided with bathing trunks. One matron supervises the showers for 60 children daily.

The **corridors** are preferably from 14 to 17 feet wide, with rooms only on one side and windows on the other. The walls should be made of light-colored, dull-finished brick, and the floors of cement or some similar substance. In two-story buildings it is important to have at least two stairways, one at each end of the building, leading directly to exits. They should be enclosed in wire glass and steel, or other fire-proof partitions, from top to bottom, access being by means of self-closing fire-proof doors, held open by fusible links.† Cement and steel make the best material for stairways which ought to be from 4 to 5 feet wide. If wider than this, a third line of children may descend without the protection of a hand rail. The height of the risers is usually 6 inches; width of tread 10 to 12 inches. There should be a rectangular landing halfway up, double the length of the tread. The lower part of the balustrades is made solid; the upper of some easily cleansed metal work, finished with a hand rail 3 feet above the floor and another hand rail at the outer end of the tread, jutting out from the wall. The number and width of stairways may be apportioned as follows: "Four feet for the first 50 pupils, and 6 inches additional width for each additional 50 pupils." It is better to make corners rounding where possible.

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* Perry, C. A. "Social Center Features in New Elementary School Architecture;" "Wider Uses of the School Plant." Pub. by the Division of Recreation, Russell Sage Foundation, No. 120 (25c.).

† From a Sage Foundation pamphlet on fire prevention, quoted by Rapeer.

Doorways.—"For the exterior exit there shall be an allowance made of 15 lineal feet width of doorways for the first 500, and 6 inches additional width for each 100 additional persons. These widths should be increased by 50 per cent. if there be an auditorium on the first floor or basement which has not direct exits." It is important to provide the exit doors with panic bolts.

Basements should be 10 feet in height for light, room, and ventilation, the floors of cement, and the ceilings of fire-proof material, with no closets under the stairways. In rural schools the gymnasium, dynamo, gasoline engine, power pump, water tank, tubs for the laundry, drying room, coal room, bulb room, dark room, and furnace are placed in the basement (Fig. 265).

Other Fire Laws.—If a large school, each story should be constructed with fire-proof partitions, so that one section may be completely shut off from the rest.

The heating plant should be separated from the rest of the building by fire-proof walls, ceilings, and doors.

The attic should be cut by at least one partition to prevent draughts.

There should be automatic sprinklers in store room and fuel room.

There should be a fire drill every two weeks, with not only the usual alarm gongs about the building, but an alarm to the fire department as well.*

Water Supply.—It is most important for school authorities to see that samples of drinking water are frequently sent to the state laboratories for bacteriological and chemical examination. Driven wells with a force pump and a cover are regarded as the safest for the country school house. A drinking fountain can be attached to this. An excellent description of this may be found in "Rural School Houses and Grounds," F. B. Dresslar, U. S. Bureau of Education, Bulletin No. 12, 1914, Washington, Government Printing Office.

The drinking fountain is taking the place of the common or the individual cup. The pneumatic pressure tank, pump, piping, and drinking fountain affords running water, and costs from $100 to $250. It will afford power for the sanitary drinking fountain, the sink for washing hands, and sanitary indoor closets instead of the ordinary outhouses.†

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* Cook, W. A., "Protection against Fire and Panic." School House Sanitation, U. S. Bureau of Education, Bulletin No. 21 (1915), whole No. 648.

See Rapeer, "Educational Hygiene," p. 336, and Cooper, F. I., The Planning of School Houses Against the Fire Hazard, Fourth International Congress of School Hygiene, ii, p. 39; School Buildings and Grounds, Extract from iii of the Tenth Annual Report of the State Department of Education, Albany, New York.

† Rapeer, *ibid.*

Simple apparatus attached to hydrants can be obtained for $10. In large city schools, drinking fountains should be placed in the corridors. They require daily cleansing and in time of epidemic it does no harm to sterilize them occasionally with alcohol.

In estimating *dust* a counting cell is used. It settles in the counting cell into two layers the greater number of which are on the surface, are exceedingly microscopic and made up for the most part of mold spores. The lower layer consists of fewer and larger particles composed of vegetable fiber and inorganic matter. The schoolroom air in ordinary localities averages about 500,000 particles to the cubic foot but in dusty neighborhoods may have as many as 2,000,000. Usually school dust is not especially harmful except in epidemics.* Coal dust is not serious apparently.† Dust comes from dirt brought in by children's shoes, or from fresh air intakes, from chalk troughs, erasers, door mats, sweeping and dusting.

Janitors should be educated in principles of ventilation, heating, pure and clean air, lighting, etc. They are responsible for a neat appearance outside, and for freedom from mud, etc., so that the children may enter the schoolroom with shoes as clean as possible. Clean window panes shut out about 10 per cent. of the light. In view of this the necessity of cleanliness is apparent. In public schools windows are usually cleaned five times a year. In some private schools they are cleaned every two weeks. The floors are scrubbed usually five times a year, and swept every night. Kindergarten rooms are scrubbed from two to five times a week, and swept twice daily. Sweeping is done preferably with standard sweeping compounds, or sawdust moistened evenly with a mixture of oil, turpentine and disinfectant, or with hair or fiber brooms of a self-oiling variety. A vacuum cleaner is by all means better, as it removes dust. Those recommended for schools are Atwood and Spenser, Turbine and Tulc, and Connorsville. There may be others of more recent date. Rooms should be dusted in the morning before school with a damp or oiled cloth. Erasers and door mats require beating two or three times a week, and blackboards require cleaning daily. Lockers should be scrubbed at the end of each term.

For disinfection, the following method is used at the School of Education, University of Chicago, though it is to be understood that disinfection is less and less used:

Method of Carrying out Disinfection.—

Required:

One 3-gallon pail.

One 20-inch dish pan.

For disinfecting a room of 200 cubic feet use:

Formaldehyde..................	20 ounces (600 c.c.)
Potassium permanganate.......	10 ounces (300 grains)

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[*] Winslow, C. E. A., Studies of Air Conditions in New York Schools, Fourth International Congress of School Hygiene, ii, p. 211.

[†] Mavrogardato, A., Experiments on the Effect of Inhalation, Jour. Hygiene, xvii (Oct., 1918), p. 439.

Directions:

First, seal up all window frames and other cracks and openings, such as ventilators and hot-air registers, etc.

Place the pail in the pan in the center of the room.

Measure the cubic space of the room.

Then throw into the pail the amount of permanganate necessary for the size of the room to be disinfected, and add next the correct amount of formaldehyde, stirring gently to thoroughly mix the two materials.

Leave the room as soon as the stuff in the pail begins to "boil," and seal up the door from the outside.

Leave shut for six hours.

Note.—On opening a room it is desirable to get rid of the fumes quickly. The most efficient method of accomplishing this is to open the windows for a few minutes, hang up a sheet in the center of the room and spray it liberally with ammonia water, then close the room for 20 minutes, afterward airing it for 10 minutes.

An excellent *bibliography* may be found in School Buildings and Grounds, from vol. iii of the Tenth Annual Report of the State Dept. of Education, Albany, the University of the State of New York.

Corwin, R. W., "The Modern Model School House on the Unit Plan." The Franklin Press, price 50c.

Mills, W. T., American School Building Standards, U. S. Bureau of Education, Bulletin No. 5 (1910), whole No. 444.

Ingersoll, L. R., A Means to Measure the Glaze of Paper—Outline of the Theory and Construction of the Glarimeter, Elec. World (March 21, 1914).

Report of British Assn. Committee on School Books and Eye Sight. Manchester (1915), Abstract in London Illuminating Engineer (Oct., 1915), p. 425.

Magazines:

American School Board Journal (architectural).
Architectural Forum, Boston,
Ventilation, heating, lighting, etc., will be found discussed in engineering magazines.

Woodbridge, S. H. (Mass. Inst. Tech.), Air and Its Relation to Vital Energy, Connecticut School Document No. 5 (1904), p. 12.

HEATING AND VENTILATION

HEATING

Heat is essential for comfort and to a certain extent for a maximum of work and must be available in temperate or cold climates or buildings cannot be used at all. Ventilation, while necessary for the protection and maintenance of health, is on the whole less vital than heat. The importance of fresh air and comfortably heated rooms reaches its maximum in school buildings where the health of school children and their immediate ability to do school work is at stake. Disadvantageous conditions of this kind quickly produce disastrous results, which visitors are more likely to see than teachers, who as a rule quickly become used to unfavorable conditions. The bright eyes, rosy cheeks and alert manner of children in open-air schools testify to the necessity of these phases of school hygiene.

Because ventilating media are often used for heating, it is sometimes assumed that they are inseparable. This, however, is a mistake as the kind of building, its size, its location, the average temperature of the climate where the building is located, etc., determine the method to be used for either heating or ventilating or the combination of the two. As a general principle it may be said that the simpler the type used the better, but there is hardly any method of heating or ventilating that will not serve admirably if it is used in the right place. As there is such a great variety of climates and altitudes existing in the United States, it is easy to see that if satisfactory results are to be obtained discrimination must be used in choosing the type. Windswept plains, the cold northern states, and the warm southern states, the large city and the rural district present differences that only the expert heating engineer can handle competently. There are heating and ventilating quacks just as there are medical quacks and the results of one are as bad as the other. Sometimes communities expect their school superintendents, principals, boards of education, etc., to act in the capacity of heating and ventilating engineers; that is, they expect the above officials to choose heating and ventilating apparatus. Considering the multitude of highly scientific problems that are involved in such choice, the expensive character of the equipment and, most of all, the intimate relation between health and school progress and proper temperature, humidity and fresh air, it pays from every point of view to obtain the services of heating and ventilating engineers and when once the problem has been turned over to them to allow them to assume full responsibility for successful results.

Standards of Heating.—Heat is best generated in a *central plant* safely situated and so constructed that dust, gases and odors cannot escape into the building. The *size of the plant* is important, at least it is desirable that it be sufficiently large to meet the effect of the lowest possible temperatures or the strongest winds. Where heated air is used it is necessary, in order to prevent devitalization of air, to plan on a scale of sufficient size so that a large quantity of moderately heated air may be delivered rather than a small quantity at a high temperature. In mild climates and in small buildings, it is sometimes possible to install hot-air furnaces, depending upon the teacher to report temperatures either too high or too low. Even in small systems this is unsatisfactory, however, as both teachers and pupils become oblivious of temperature conditions when the school work is absorbing. In large systems *automatic regulation* is a necessity if the variation in temperature is not to extend beyond one or two degrees.

The *fresh air intake* in large systems should be taken from a point above the roof if possible and in any case well above the ground. It is better placed on the south side of the building because there is a difference of five degrees between the north and the south sides, and by making this provision it is possible to save considerable fuel.

Temperature.—Experiments show that the best mental activity is secured at a temperature of 50 degrees. Such a temperature requires extra clothing and is rather low for hand work. There has been an effort to adopt 65 or 66 degrees as the best general temperature standard for school activity but pupils are accustomed to warmer temperatures in their homes so that 70 degrees has been universally adopted. All types of heating apparatus should guarantee a temperature of 70 degrees for study and recitation rooms in the coldest weather. During physical education periods fresh unheated air may be admitted directly to the gymnasium. As temperature is the only condition which really affects the conscious comfort of teacher and pupils, provided the humidity is normal and as it actually bears a distinct relation to mental and physical progress, it is very important to keep the temperature even and never above 70 degrees.

Humidity.—The ideal air condition is a sunny, breezy spring day with an outside temperature of 70 degrees, and a relative humidity of 50 or 55 per cent. (saturation being 100 per cent.). In cold weather, on account of the frosting on windows and the drier condition of outside air, it is not possible to secure such conditions, the humidity at times getting as low as 40 per cent. relative humidity at 68 degrees dry bulb or room thermometer temperature. This is low but it is within normal limits. A degree of physical comfort which is equivalent to the ideal condition may be secured at a temperature of 63 degrees dry bulb if there is a humidity of 62 per cent., but it is advisable if possible to keep the relative humidity at a point which is equivalent to the ideal as above noted for the actual outside temperature when the inside temperature is 70 degrees. The higher percentages of humidity have a decided economic advantage in the saving of fuel and their effect on health is not supposed to be detrimental, but they result in discomfort and probably less intense work on the part of the pupils. Humidification really concerns ventilation more than heating and for some reasons would be better discussed there. Wherever considered, the point to be emphasized is the necessity of providing ample moisture to every heating system from the smallest furnace to the largest plant, for although studies of humidity show that there is very little relation to the health of the school child, there is no question but that overheated air draws moisture from the skin and this produces discomfort. Comfort is worth considering and depends as much upon humidity as upon temperature. The Sling psychrometer or hygrometer is the usual instrument for measuring humidity.

Heating.—Except where stoves are used in very primitive schools, heat is supplied to school rooms from a central plant located in the basement or in an adjoining building or from a power house which supplies a number of buildings. Stoves simply radiate heat. Furnaces send the heat upward through flues, by gravity or forced blast (fan). Hot water, or vapor or steam is generated in the basement or power house by furnace fires or electricity which heats the water in the boilers to the temperature required. From the boiler the heating medium is carried by pipes to the school rooms, there circulating in radiators. All heat derived from a heating mechanism in the room as from a stove or radiator, no matter where the source of heat, is called *direct heating.*

Ventilation.—Air used for ventilating purposes must be heated to a temperature of 70 degrees before it is distributed to the rooms. Fresh air intakes of various sizes are employed, depending upon the number of pupils to be supplied. No matter what type of heating apparatus is used, the air to be used for ventilation derives its heat by circulation around or between the various parts: jacketed stove, radiator coils, etc. After it is heated, gravity or a fan forces it on or a vacuum draws it through flues to the rooms. This air of course not only ventilates but also supplies part of the heat. When the heat is derived from ventilating air . . . it is called *indirect* heating. Heat and ventilation are frequently supplied in combination: direct-indirect, unit, split and combination types which will be considered later.

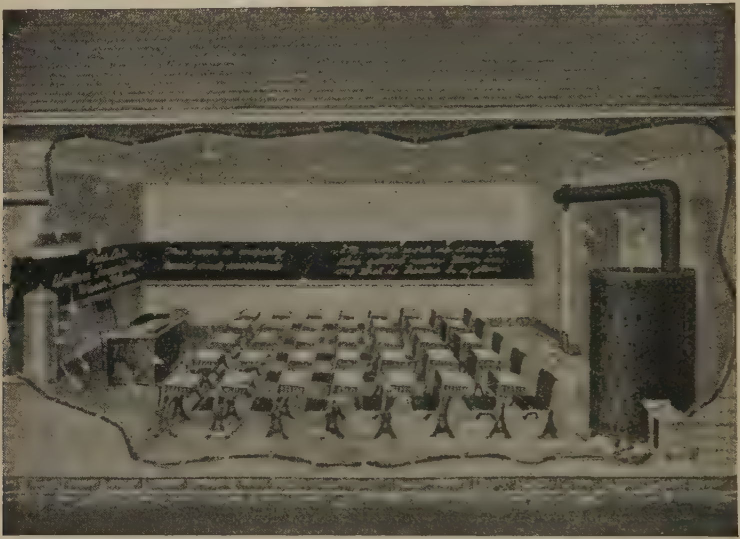


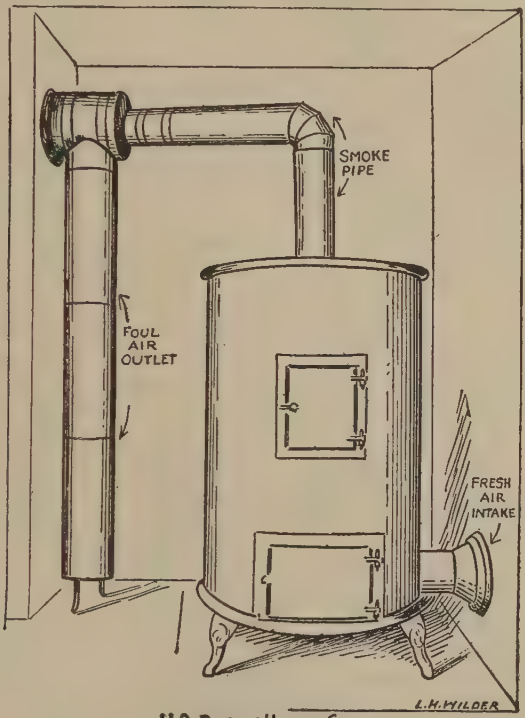
FIG. 268.—Circulation of heated air in a well arranged schoolroom. (The Rural School Messenger) Published by the First District Normal School Kirksville, Mo., Vol. 5, No. 2, Oct., (1915).

TYPES OF HEATING

Stoves, furnaces.
  (*a*) Using gravity circulation of heated air.
  (*b*) Using forced circulation.
Gas.
Vapor.
Hot water.
  (*a*) Using gravity circulation.
  (*b*) Using forced circulation.
Steam.
  (*a*) Gravity air indirect.

(*b*) Direct-indirect.
(*c*) Unit "systems."
(*d*) Forced blast, using air only.
(*e*) Forced blast supplemented by direct radiation.

The jacketed stove for portables, one room and small rural schools, where there is no basement is enclosed by a sheet iron jacket, the inside of which is 18 to 24 inches distant from the stove. The jacket is about 6 feet high and extends to the floor. A cold air duct leading from the outside of the building underneath the floor opens beneath the stove, and the air which enters from it is heated by the radiation from the stove and rises to the ceiling. Such stoves are placed in the schoolroom close to the side of the room, either in the middle or in a corner. Many of these stoves have an evaporating apparatus. They demand attention, as their value is lost if the fresh air chamber is broken or disconnected or if there is re-circulation of room air, and dust may be distributed in the room if dirt and debris accumulate in the spaces surrounding the stove and its jacket. Where it is necessary to use equipment of this type the laws of Ohio can be depended upon as a standard.



U.S. PUBLIC HEALTH SERVICE

FIG. 269.—Type of jacketed stove. "Rural School Sanitation." Clark, Collins and Treadway, Public Health Bulletin No. 77, June, 1916. Treasury Dept. U. S. Public Health Service, p. 37.

Furnaces.—For the most part stoves of this kind have been replaced by furnaces, which supply both heat and ventilation through flues to the various rooms. The gravity furnace is placed in the basement and receives outside air from several sides so as to catch any

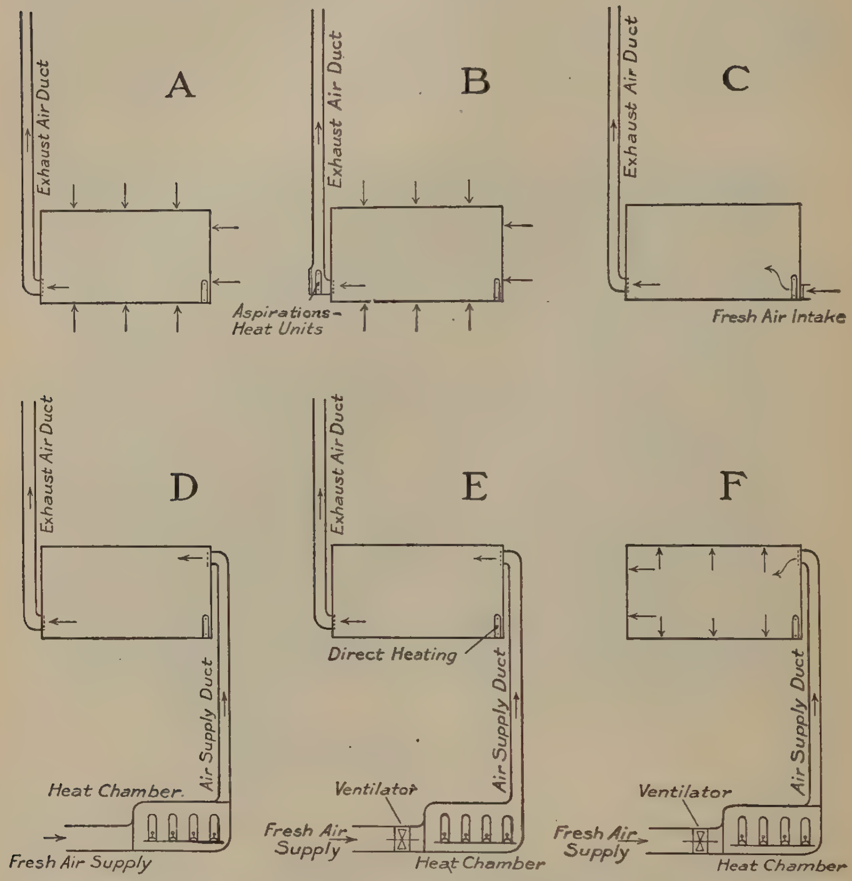


Fig. 270.—Different Types of Heating and Ventilation. Kruse und Selter "Gesundheitspflege des Kindes."

wind that may be blowing, the air inlets being under control by dampers. There are devices for furnishing moisture but in most gravity furnaces there is no provision made to avoid the re-circulation of schoolroom air. Aside from this objection the gravity furnace is good for small two-story buildings with four rooms or less. It is not good for one-story buildings. The following rules apply to gravity furnaces only.

The volume of the house divided by 50 equals the square feet of heating surface in a furnace radiator. The volume of the house divided by 20 equals the number of square inches of grate area in the furnace. Divide the volume of the room by 20 and the square root of the quotient will be the diameter of the furnace pipe for the first floor rooms; for the second floor rooms, divide the volume by 25 and the square root of the quotient will be the diameter of the furnace pipe.*

The forced blast type of furnace combines both heat and ventilation, a fan being used to draw fresh air from without and later to force it over the heating surface of the furnace and on through the ducts into the rooms. Sometimes parts of the building requiring minimum ventilation are heated by a small steam or hot water heating boiler, attached to and receiving its heat from the furnace. Halls, toilet-rooms and rooms which are liable to be used when classes are not in session or after school hours come under this category. Several furnaces can be made to serve as a unit, but it entails so much labor that it is not practical for large buildings. The advantages of furnace heating are simplicity, cheapness, economy and quickness in securing results in mild weather. The objections are the escape of gases, dryness of air notwithstanding efforts at humidification, and difficulty in apportioning heat properly to the various rooms.

Gas radiators are manufactured which are heated by Bunsen burners in direct association with the radiator. Except in a few schools located in mild climates, they are used only to furnish additional heat where ventilation is already provided. Their chief advantage is that of localizing heat to any section of the room. On the whole they are dangerous. They are sometimes inefficient because their heating capacity depends upon the amount of gas pressure. Gas is also used as a fuel for regular furnaces and steam systems. In this connection it acts admirably.

Vapor heat which is controlled by a patented device is a modification of steam heat, the difference being that the vapor is used as it first comes off the boiler instead of beyond the boiling point as in steam. As there is no pressure, the steam is not superheated and therefore is not devitalized. This system requires large supply pipes and large amounts of radiation. It acts by condensing the vapor in the radiators which produce a vacuum thus drawing in more vapor. Except in mild climates and with gravity indirect systems (see ventilation) it has no advantage over steam for school heating.

Hot water is advantageous because it is heated only to 180 degrees, thus devitalizing the air less than steam. It is, however, not practical except in mild climates where less heat is required. Its use is dependent upon the topography of the site, grades, elevations, etc., and upon good available exhaust steam. Hot water is more difficult to handle than steam because it cannot be shut off in the basement, or elsewhere. Usually enough coils are provided to take care of the ventilation at maximum conditions. Modification of the temperature of the air used for ventilation is produced by a device called the "by-pass" which is a damper permitting more or less outside air to mix in the ventilating chamber according to the need. As the water in the coils is kept at a constant temperature the function of the by-pass is simply to reduce the temperature of the ventilating air. In a hot water system the air for ventilation is heated to 70 degrees at a central point by hot water radiators and a blast or fan then forces it on. Heat for the supply of transmission losses is derived directly from hot water coils in the rooms. Hot water cannot be controlled thermostatically.

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* Allen, John R., "Heating and Ventilation."

Steam is the most universal medium for heating schools of any size. It is advantageous because the radiator can be diminished in size and because rooms can be warmed by it quickly. Steam also can be used as a means of power for driving the ventilating fans if the pressure is sufficiently high. Five to ten pounds of pressure is enough for the heating system if electricity is available for power for the fan. Some of the forms in which steam heat is used are the following:

(*a*) Gravity indirect
(*b*) Direct-indirect
(*c*) Unit systems
(*d*) Forced blast
The medium is air.
(*e*) Forced blast supplemented by direct radiation in which direct radiation is used for the heating medium and air as a ventilating medium only.

Gravity Indirect.—This type of heating supplies heat only by means of the ventilating air which is heated around stacks of coils in rooms in the basement and forced on up through the flues into the schoolrooms by the pressure of the wind outside. As this is usually uncertain some direct radiation is often supplied also. While in gravity systems it is possible to handle rooms on the windward sides of buildings satisfactorily, it is very difficult to supply ventilation or indirect heat to the leeward sides. Rooms in the latter situation are not only deprived of the usual currents of air circulating on the windward side, but there is also a tendency to suck air out of the rooms by a partial vacuum created at a point outside of and beyond them where windward currents of air coming around either side of the building meet.

Direct-indirect.—In this type the radiators are placed in contact with the outer walls of the room, the same sides on which the windows are placed. Each radiator is directly connected with the out-door air through a grating which is the outer boundary of a little chamber in the wall controlled by a damper to let in more or less air. Through this chamber the outside air is conducted to a small chamber underneath the radiator. From this point it becomes heated as it circulates between and around the coils in its ascent. Thus by the same radiator heat is supplied directly and ventilation indirectly. This is a poor system except in those parts of the building which require minimum ventilation as in retiring rooms and locker rooms. In classrooms where there are many pupils it is not possible to obtain adequate ventilation if proper heating is secured or proper heating if the right amount of ventilation is provided. It is very clear that on the leeward or protected side the wind will be insufficient to secure adequate ventilation and on the windward side, if the rooms are close to the ground, soot and dirt will be blown in, thus injuring the decorations. In the South where very little heat is needed and in places where wind pressures are strong and windows kept open, it may be used advantageously with vapor or hot water. This type of equipment should always be provided with direct radiation in halls, toilets and rooms requiring direct heat even when used in mild climates.

Unit System.—This is like the direct-indirect system except that each radiator is surrounded by a cabinet and is provided with a small fan placed in the top of the cabinet which distributes the heated air. The outside air is allowed to enter the cabinet at a point in the wall above the floor. The manufacturers claim the following advantages: First, that it can be handled by teachers. As has been said before, teachers have no time to use for this purpose. Second, if the heating and ventilating of each room comprises a unit, windows can be opened without disturbing the general distribution of heat and air. This is true, but if direct radiation is provided for schoolrooms the opening of windows in any room will produce very little effect upon the ventilation of any other room, no matter what system is used. The points against this type for school use are expense, noise, and the re-circulation of air. The best architects approve its use in many places but not for schools.

Forced blast heating is the type in which outside air is heated by coils in the basement (indirect) and forced on by a fan or fans through the ducts and vertical flues into the rooms. In large buildings in mild climates it is the ideal system. Its limit depends upon the temperature to which the air must be raised to heat the building in very cold weather. If in such weather it is necessary to raise the temperature to 90 degrees it is better not to use it alone but in combination with direct radiation. In the unexposed portions of buildings such as auditoriums, gymnasiums, etc., excellent results are secured if forced blast is used alone. The rest of the building, as has been said, must be provided with both systems unless wind conditions are bad when careful designing is necessary to avoid defective distribution.

"Split System" or Combination Type.—This has practically been described above. As heat in the forced blast system is derived solely from the ventilating air and as it is of great importance to keep this air from devitalization it can be seen that it is not appropriate for very cold climates. Consequently the split system is very popular. It includes direct radiation in the rooms for heating and indirect for ventilating, supplied by the forced blast system. Systems in which the heat is generated in a central plant should be controlled by thermostats in each room, sensitive to the degree of temperature. If the temperature rises above the point set as correct, the thermostat opens the cold air damper; if it falls below, on the other hand, it opens the hot air damper. This air enters the mixing chamber and then passes to the over or underheated room. In the split system the indirect coils are so controlled by thermostatic regulation as to introduce the air into the rooms at a temperature of 70 degrees regardless of outside temperature. The room control operates the direct radiation, keeping the temperature of the room at any point desired. Thermometers should be placed in each room, in the path of the air leaving the room on a level with the heads of the pupils while sitting. As they are a temptation to mischievous children a height of 5 feet above the floor level is more practical.* It is very desirable for school children to learn to keep room temperature records; it may very well be a part of their training in hygiene to keep a daily temperature chart on the wall.

VENTILATION

The aim of ventilation is to renew the aerial envelope evenly about the bodies of people by the passage of air, and to remove contaminated air promptly and directly, so that there may be no stagnant spots. "Pure outdoor air contains, per 100 volumes, 20.81 parts of oxygen, 79.15 of nitrogen, and 0.04 of carbonic acid gas. Air expired by an adult man, when deprived of the water vapor acquired and reduced to the same temperature as when inspired, has 4.78 parts less of oxygen and 4.34 parts more of CO_2, and 0.15 part more of nitrogen."†

Expired air also, which is only one or two degrees less than body heat, adds both heat and moisture to the atmosphere. As humidity always decreases the ability of the body to throw off heat, and as perspiration contains inorganic salts and fatty acids, which often undergo decomposition, producing noxious odors; moreover, as schoolroom air always contains dust and bacteria, and sometimes contains vitiating gases which escape from furnaces and stoves, it becomes very essential to supply large amounts of pure air and to supplant foul air. Accepted standards for proper ventilation are a minimum of 30 cubic feet of air for each person per minute. Each child vitiates 100 times as much air in an hour as it will breathe, and the amount breathed depends on the physical state and age of the child. Primary children at ordinary quiet work breathe 20 cubic feet of air each hour and, therefore, require 2,000 cubic feet. Upper grammar grade children breathe 25 cubic feet, and high school children 30 cubic feet, an hour. In a standard schoolroom 25 × 30, with ceiling 13 feet high, and containing 50 pupils, a minimum of 1,500 cubic feet per minute is required, with a complete change every seven minutes.

The velocity of air can be accurately measured by the anemometer. Its use is essential where ventilation depends upon gravity or mechanical systems.

Fresh heated air should enter the schoolroom from a duct opening 8 feet above the floor level on an inside wall. The opening should be supplied with shutters that can direct the air so that it will travel across the upper part of the room, down the opposite wall, and back again in the lower part of the room to exit flues near the floor on the same wall with the entrance flue, or if the dressing room is behind this wall, the exit openings may be through the lower part of the dressing room, thence upward, passing over the children's garments to exit flues in the upper part of the dressing room.

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* Linneus, Neal Hines, Some American Schoolrooms, Fourth I. C. School Hygiene, ii, p. 11.

† Shaw, "School Hygiene." Crowder, T. R., On the Re-inspiration of Inspired Air, Archives of Internal Medicine, xii (Oct., 1913), p. 420.

Fresh air is distributed either by dilution or displacement. Dilution of air is caused by differences in the temperature of objects, walls, windows, etc., being cold; stoves, radiators, animals, etc., generating heat. These factors produce upward and downward currents, whether air is fresh or foul, on the principle that heated air rises, and cold air falls. Ventilation by displacement occurs when windows are open on each side, so that the wind causes complete horizontal displacement. When seats are stationary it is possible to use a type of ventilation based upon the vertical displacement of air. In this type, the warm fresh air enters through openings in the floor under the seats, rises directly to the ceiling and passes out through vents at this level. This is the system usually used in theaters and in the large assembly rooms or auditoriums of schools.

The chief ventilating systems are the gravity indirect system and the mechanical systems. Of the latter there are two types: the vacuum system and the plenum system.

The **gravity system,** illustrated by the jacketed stove and furnace, depends upon pressure of the wind from the windward side of the building in the fresh-air duct, and also upon temperature differences—hot air rising, and cold air falling. If the thermostat is used, it automatically controls the temperature differences, so that if rooms are heated above the standard fixed, cold air will be drawn in and *vice versa.* The greater the difference in temperature between the air outside and inside, the stronger is the pull in the supply flues. The foul air outlet, therefore, is made much more effective if aspiration is produced by a gas jet which is kept burning in it. When the rooms are warm, thermostats call for cold air, which cools the vent flues also, so that they do not draw and there is air stagnation. This makes it necessary to depend upon open windows in the spring and fall in rooms which are located on the leeward or neutral sides of the building. If the teachers forget the windows, the floors are likely to become cold, because as soon as the air from the windows has cooled the room, the thermostat calls for warm air from the supply duct. This soon heats the ventilating flue near the floor on the inside wall, which then becomes an attraction for the cold air from the windows, resulting in cross circulation.

With the gravity system, rooms on the *leeward* side have extremely poor circulation of air. If the windows are open, warm air, being lighter, passes out both at the top and the bottom. Heated air from the radiators under the windows passes directly out of doors. Heated fresh air from the supply flues passes straight across the ceiling and out at the window tops, never approaching the breathing zone. The pupils, therefore, receive very little fresh air. These unfortunate adjustments make mechanical methods necessary.

The **exhaust** or **vacuum ventilation system** is so constructed that air is exhausted from the rooms by fans (usually placed under the roof) which produce a partial vacuum, thus drawing in fresh air from the fresh-air intake in the basement, but also drawing in foul air from hallways, etc., through cracks under the doors. It is, therefore, a better system for auditoriums than for schoolrooms. Small exhaust fans can be used for drawing air from the corridors through toilet rooms and heat, steam and odors from domestic science rooms.

The **plenum system** or **forced blast** is constructed so that fresh air is driven into the room by means of a fan. This creates a density above that of the outer air, thus driving out foul air. By this system it is possible to measure exactly the amount of fresh air furnished to each room. There are many mechanical variations for carrying the air to the rooms such as the single duct, the plenum chamber, the reheater coils in flue, the overhead or downward distribution, the mush room or upward distribution, etc. Considered as a whole it is the most perfect single system known. Sometimes, especially in buildings of four stories or more, the vacuum and plenum systems are combined to excellent advantage. Some architects believe that artificial heating and ventilation will never solve satisfactorily the problems of air circulation in the schools and that open-air schools will eventually replace the unsuccessful attempts of mechanical systems. All good school architects regard their problem essentially that of bringing spring out-door conditions into the school by mechanical means.

Recirculation of Air.—As it is easy and financially economical to recirculate air, apparatus constructed for this purpose has been installed in many schools. School air quickly becomes contaminated. People who advocate this system, therefore, have devised various means of obviating the difficulty. The air washer, the air filler and the ozone apparatus are mechanisms in point. The true function of the air washer is to remove dirt and soot from air in very smoky districts or from inlets near the ground. Changes in schoolroom air are obviously of a different nature. It is the chemistry—not the mechanics of air that need changing. With air washers, however, it is probably permissible to recirculate a portion of the room air if it is mixed with fresh air, but it increases the humidity of air to so great an extent that it produces great discomfort and is very impractical. The air filler and the ozone apparatus have been proven scientifically inefficient. They are also very much more expensive than the ordinary method used in which fresh air alone is used. Recirculation of air is prohibited by the Ohio State Laws.

State Laws giving proper consideration to the heating and ventilating of school buildings are on the Statute books of New York, Massachusetts and Ohio. The following books are of value:

"Heating and Ventilating of Buildings," Carpenter.

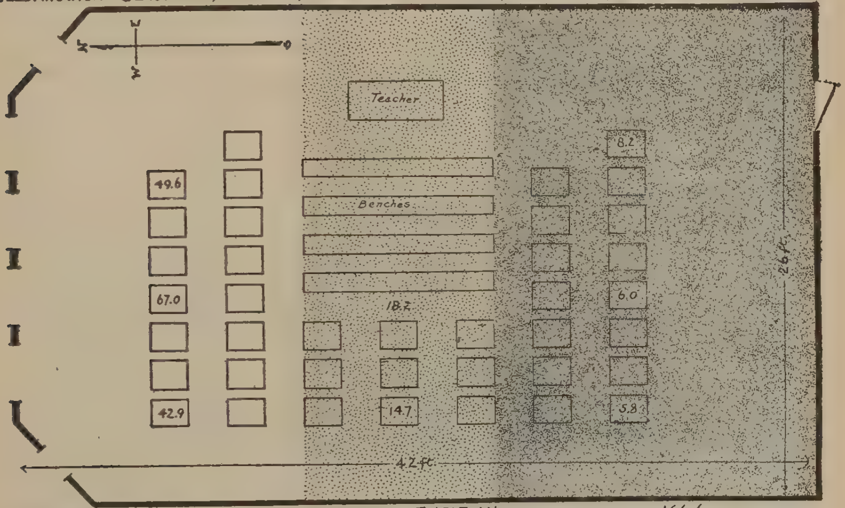
"The Mechanical Equipment of Buildings," Harding and Willard, vol. 1.

The author is indebted to Mr. Dwight R. Perkins of Chicago for general oversight of the material on School Architecture, to a "Lecture on Heating and Ventilating" delivered at the University of Chicago Teachers' College Summer Course by Mr. R. W. Yardley formerly with the firm of Perkins, Fellows and Hamilton, Architects, Chicago, and to Mr. A. J. Dunn of the same firm for correction and further suggestions.

LIGHTING

The ordinary standard of light is the foot candle which is a measure of the intensity of light as a degree Fahrenheit or Centigrade is the measure of the intensity of heat. The standard foot candle corresponds approximately to an old fashioned tallow dip with a wick about three-eighths of an inch in length.

ILLUMINATION—CLASSROOM, GRADE IV, CHESTERTON HIGH SCHOOL, CHESTERTON, PORTER COUNTY, INDIANA.



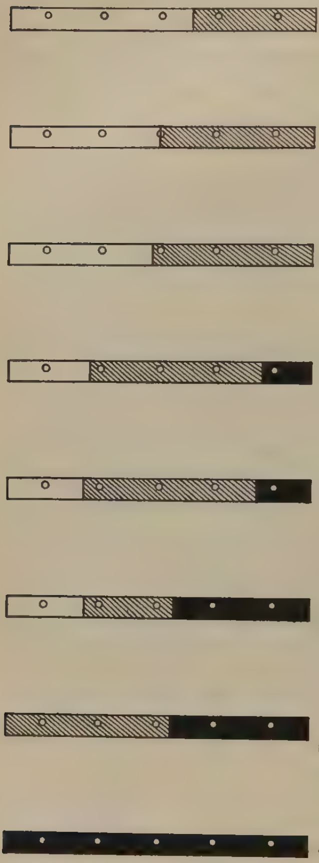
WEATHER CONDITIONS—FAIR, 2:20 P.M. MAY 3, 1915. WINDOW ILLUMINATION 166.6 FOOT-CANDLES.
U.S. PUBLIC HEALTH SERVICE

FIG. 271.—"Rural school sanitation," Clark, Collins and Treadway, Public Health Bulletin No. 77, June, 1916, Treasury Dept., U. S. Public Health Service, p. 37.

There are two ways of securing intensity of light sufficient to prevent eye-strain: first, natural light; second, artificial light. Work can be done comfortably with a lower degree of intensity from artificial than from natural light. From every other standpoint, however, it is obviously of great importance to secure natural light if possible.

In a room of north exposure on a clear day in the middle of spring or summer (Fig. 271, 272) the desks nearest the window are located in an intensity of light equal to 40 or 50 foot candles per square foot; desks on the opposite side of a room 24 feet wide have an intensity of light equal to three foot candles. Three foot candles is the minimum for class rooms: from 6 to 10 is good lighting. If each 2 square feet of floor space in the class room requires a minimum of one foot candle, the same space requires only 0.8 of one foot candle for auditoriums and gymnasiums and 0.5 for stairways and halls.

To secure sufficient amount of intensity for the seats in the darker section of a schoolroom it is important that no desk be farther from the window wall than one and one-half times the height of the window glass above the desk surface. Great effort has been made to have the light come in from the left. If the light depended upon comes from this direction only the windows should start 15 to 18 inches from the rear wall leaving not less than 6 to 7 feet of blank wall at the other end. Further, the top of the window should be square, should extend to a distance within 3 inches of the ceiling and the extent of the window surface should equal one-fourth or one-fifth the floor area. A foot of light coming in from the top is worth more than 3 or 4 feet at the bottom of the average window, primarily



March 12 M. Sky gray white evenly distributed clouds.

Jan. 12 M. Blue Sky with reflex from near by buildings.

March 10 A. M. Sky lightly covered with clouds.

March 10.15 A. M. Sky lightly covered with clouds, children are at their desk.

Dec. 11.15 A. M. Moderate uniform clouding of the sky.

Dec. 11.15 A. M. Moderate uniform clouding of the sky, children are in their seats.

Dec. 11.15 A. M. Sky evenly darkened, light rain with some snow flakes.

Jan. 12 M. Uniformly dark sky, light rain.

FIG. 272.—"Gesundheitspflege des Kindes." (Kruse und Selter.)

because light coming up from below produces strain of the ciliary muscles and uses retinal energy designed for purposes of vision, to the point of retinal exhaustion; also because it produces contraction of the pupil thus reducing the amount of useful light entering the eye, and finally, because it brings the glare of the page annoyingly into consciousness, in this way distracting the attention away from the subject matter with which it is dealing. It is important for light to come from above, in the schoolroom especially as most of the work done with the eyes is placed below them on the desk. When there is proper provision for this arrangement the light will then be reflected into the eye from the surface of the material under inspection.

Various arrangements are provided so that light may come in from above and not from below.

The method of procuring "top lighting" is by means of sky-lights in the roof with shades to control the light. This is only possible in one-story schools such as the Skoki School near Chicago. The ceiling, however, can be used as a light reflector, the reflector being a highly polished horizontal inside shutter 2 or 3 feet wide and placed 2 or 3 feet below the top of the window. Such reflectors should be fastened in place with a hinge that will allow it to be inclined at different angles varying with the different inclination of the sun's rays at different times of the year. When high buildings obscure the light (Fig. 273) *outside*, reflecting shutters are of value by reflecting light from the sky on to the ceiling. Reflectors of this kind are made of milk or prism glass.

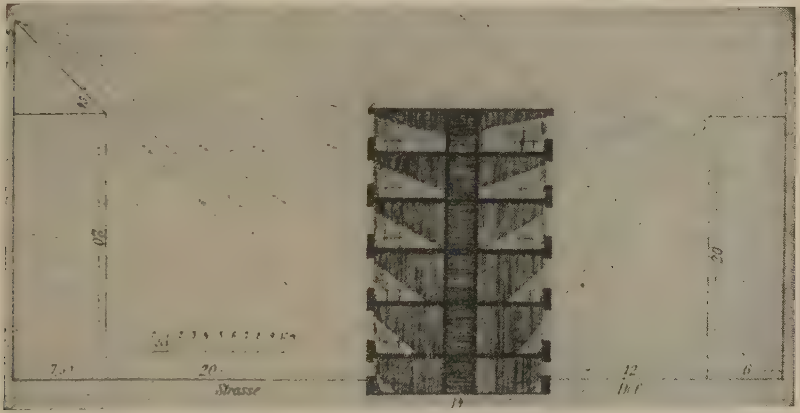


FIG. 273.—Interference of neighboring buildings in the amount of light. "Gesundheitspflege des Kindes." (Kruse und Selter.)

Light from other directions: If the windows are placed sufficiently high and furnished with the proper shades or horizontal shutters, the light may be admitted from any direction, even from the south. Ordinarily with lighting from the left, the lower margin of the window in primary class rooms is 3½ feet above the floor; in grammar-grade rooms 4 feet, but with the arrangement above indicated windows may begin 6½ or 7 feet from the floor and the blackboards and charts can be placed below them on sides opposite other windows. Thus they receive ample light while the glare is reflected to the floor. When windows for lighting purposes are placed so high it is desirable for psychologic reasons to have some small windows at the usual height below from which to look out.

It is important to equip school windows with translucent shades, hung from the top. These are always raised when the sun is not shining through them. If schoolroom windows come below the level of the eyes, dark shades may be placed at the bottom of the window and pulled up far enough to be a protection. From the standpoint of light it is advantageous to have larger panes of glass and fewer windows. If the window glass panes are 42 × 45 inches with five windows, 160 square feet of light are admitted; if they are 48 × 45 with four windows there are 185 square feet of light. Breakage however must be considered. Probably the best windows are those divided into three sections, each swinging on a horizontal pivot. See illustrations "Open Air Schools" (Fig. 283). With this arrangement entering air can be directed upward and if each section is provided with its individual shade, the light can be very easily controlled.

Summary of Natural Lighting.—In selecting a site and plans with regard to illumination it is important that neighboring trees or buildings shall not rise more than 15° above the horizontal plane of the bottoms of the windows; that windows shall be high enough to permit light to fall at an angle of from 15 to 40° on the part of the room most distant from them, shutting off all glare of light below 15°, and that such windows be placed on all available sides of the room. Light can be augmented by light colored tinting of the walls, light colored shades that can be drawn in front of the blackboard when not in use and horizontal polished shutters.*

Artificial Light.—The requirements of good artificial light are:
Intensity.
Quantity.
Suitable quality.
Light from the proper directions.

Intensity of Light.—As has been said, the ordinary unit or standard of intensity of light is the foot candle and corresponds to a degree Fahrenheit or Centigrade which is the unit or standard of the intensity of heat. The intensity of artifical light is influenced by a number of factors; among others the amount of wattage. There should not be less than one to one and a half nor more than two watts per square foot. Preferably there should be one 150 watt lamp for a room 10 feet square.

Quantity.—The unit of quantity of light is called a lumen. It corresponds to the calorie or unit of the quantity of heat and is used by illuminating engineers in measuring the quantity of light. If it is desired, for instance, to illuminate 10 square feet to the intensity of one foot candle, 10 lumens are required. Therefore, if the light given off by a lamp of 1,000 lumens could all be confined to 100 square feet, the total light would have an intensity of 10 foot candles.

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* Daylight in the Schoolroom, Abstract of Report of Subcommittee on Conservation of Vision and Lighting in Schools, Jour. A. M. A., lxxvi, No. 25 (June 18, 1921), p. 1785.

When illuminated by electricity, the watt must be considered as the practical unit of activity or power as it indicates the energy consumed. Seven hundred and forty-six watts are equal to one horse power. Wattage is the power consumption of a lamp. The original carbon (incandescent) lamp, which is the ordinary bulb used in lighting homes at present, burns with an intensity of 16 foot candles and uses 50 to 60 watts. The following table shows the relation of lamps, watts and lumens:

TABLE 37

SIZE OF LAMP IN WATTS	CLEAR MAZDA-C LUMENS (110 VOLTS)
75	865
100	1,260
150	2,040
200	3,100
300	4,840
500	8,750
750	13,900
1,000	19,300

An inspection of the above table reveals the fact that it is greater economy to use one large lamp than several smaller ones of the same total capacity.

Three 60 watt Mazda-B lamps use 180 watts and give 1726.2 lumens.
One 150 watt Mazda-C lamp uses 150 watts and gives 2049.0 lumens.

Allowance must be made for wastage as only half of the light guaranteed by the lamp will be delivered at the working plane as useful light.

The Size of the Wire or Filament which Produces Illumination.—A filament of the carbon lamp is larger than the tungsten filament of the Mazda lamp and for this reason offers less resistance to the current of electricity. The glow however depends directly upon the amount of resistance. It can be seen, therefore, that less electricity will be required with the smaller filament of the Mazda lamp and that it will give a better light.

Light of suitable *quality, i.e.*, the color, should be that of daylight. The tungsten filament of the present Mazda lamp produces the best imitation of daylight.

Light from the Proper Directions.—*Direct* light, such as is furnished by a gas jet or incandescent lamp with a clear glass bulb, is too strong to be good for the eye, casts sharp shadows, and reflects light from desk tops, glazed paper, etc., in the form of glare. Glare itself is a quality of light which is of the most serious importance as it produces discomfort, interference with vision and eye fatigue. It can readily be avoided by frosted bulbs.

Indirect light is a better form of distribution (Fig. 274). It is such as is furnished by lamps hung close enough to the ceiling so that the inside, white, highly glazed bowl, that hangs just below the lamp, reflects the light to the ceiling, which in turn is diffused from that area throughout the room. There is an objection to this form of light, *viz.*, the bowl, which is ordinarily made of metal and is dark on its under surface, produces a contrast glare which is undesirable.

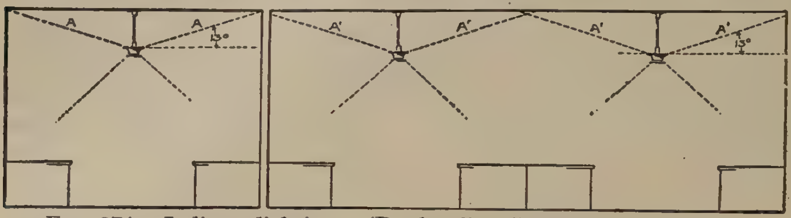

Fig. 274.—Indirect lighting. (Duplexalite General Electric Co.)

Semi-indirect light is a form in which the bowl below the ceiling light is made entirely of dense opal translucent glass. This gives both the reflected light from the ceiling and diffused rays below, and is the most satisfactory form in use. One of the best fixtures on the market at the present time is called the "Duplexalite." This fixture is so arranged that most of the light is reflected to the ceiling. About 20 per cent. of it, however, passes through the lower part of the bowl, which is in the form of a disc and made of a flat plate of dense opal glass. In an ingenious way, also, light is made to escape above and around the edge of the disc, so that the outer part of the bowl is illuminated, thus avoiding the contrast glare produced by a dark bowl. Another good equipment is afforded by a type of fixture which is represented by the Sudan bowl; here there is indirect lighting also, but it differs in the fact that the entire bowl is made of dense opal glass. Excellent equipment of this kind is offered by a number of reliable firms.

Both the indirect and semi-indirect are more expensive than the direct and the cost of maintenance is greater, usually, however, the results in lighting are superior and if conditions are favorable worth the difference in cost. If indirect or semi-indirect fixtures are used, arrangements must be made to clean the reflecting surface of the bowls at least once in three weeks in cities where there is much coal dust, and at periods of greater length in cleaner places. The fact that a 500 watt lamp kept clean serves amply in a room ordinarily requiring 600 watts is sufficient proof of this statement. If cleanliness cannot be maintained direct lighting is better, when it is so arranged that there is a frosted bowl beneath the lamp, both lamp and bowl being attached directly to the ceiling so that no dust can enter it.

If indirect lighting is used, it is important to hang the *lighting fixture* far enough below the ceiling so that the whole ceiling is lighted. The proper distance from the ceiling for these units is usually 28 inches from the ceiling to the top of the reflector. The ceiling is the secondary light source, and the larger the source the greater the uniformity of light, and the less the intensity of the shadows. The permissible distance between lighting units or lamps is 15½ feet; therefore, two such lights are necessary for each class room 24 × 32 feet, placing the lights in the middle of the area occupied by desks.

Directions, no matter how carefully presented, may fail, but the *photometer or foot-candle meter* measures accurately in foot candles the degree of intensity of illumination at any point, and it enables the investigator to know whether the illumination is uniform or not. The cost of this instrument is approximately $25.00 and may be obtained from the Duplex Lighting Works or from any of the Mazda Lamp Divisions. Every school system should have a photometer, which may be easily carried about from one school to the other, and can be used to measure light furnished by any kind of lamp.

A simpler and less accurate method of testing illumination efficiency is by the reading of diamond type at a distance of 20 inches. This the normal eye should be able to do without strain in every part of the school room.

Anyone having lighting problems can procure expert advice from companies manufacturing the Mazda lamp, all of which are licensed by the General Electric Company. Experts are supplied also by most other lamp manufacturers. These great concerns are of course interested in selling their lamp, but they seem also to be generally interested in the conservation of vision.

The author is indebted to Mr. R. C. Close, through the courtesy of the General Electric Company, for most of the technical statements in regard to artificial lighting. She is also indebted to Mr. A. J. Dunn of Perkins, Fellows and Hamilton, Architects, Chicago.

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SWIMMING POOLS

The ideal swimming pool is out of doors in a natural depression of the earth, which can be made permanently available for the purpose by lining it with concrete 1 foot thick. It is desirable to cover the concrete with white tiles, that the bottom may be more distinctly seen, but it is less necessary out-doors with strong light than indoors. Such pools should, as a rule, be surrounded by a high wall.

As climate is usually prohibitive in the all year around use of swimming pools they are generally housed in gymnasia which so far as possible should be exposed to direct sunlight. For this reason the pool should be located in a wing built for the purpose, or in a court covered over with glass—never in a basement.

An excellent presentation of their structure may be found in a book entitled "Swimming Pools." This is in the form of an advertisement distributed by The Associated Tile Manufacturers of Beaver Falls, Pennsylvania, but it contains the essentials and is elaborately illustrated. Safety devices and other adjuncts are described in a booklet entitled "Gymnasium Construction" issued by the Narragansett Machine Company of Providence, Rhode Island.

The usual *size* of swimming pools is 20 × 60 feet; 25 × 75 feet being a favorite size for larger pools (Fig. 277). The size of swimming pools is important not only from the point of view of distance, but also because the bacteriological safety and the clearness of the water depend to a considerable extent upon the amount of water. Dilution of the organisms present is to be considered.

The bottom of pools for the use of elementary children should be graded from 3 to 7 feet. Contrary to custom, two ladders should be provided at the deeper end, and one at the shallow end for pupils of this age. In modern pools the ladders are recessed in the wall.

Perhaps the best device to rescue children from drowning while in the pool is the Shepherd's Crook in the hands of the teacher. It consists of a long light pole to one end of which is fitted a hook large enough to go around the body. The length of the pole (usually 14 feet) should be a little longer than half the width of the pool.

Shower baths should be provided, as it is very important that the body be thoroughly cleansed with soap before entering the pool. Shower baths are very difficult to maintain in order. Elementary School showers require a mixing device for mixing hot and cold water. They should be arranged so that they can be operated simultaneously by an attendant. Shower mixers of the Leonard type are said to work admirably. For High School pupils, individual baths are used. The Niledecken mixer is manually operated and has a valve in each stall. This mixer is mentioned only because it is representative, there being a number of excellent mixers of this type on the market. Showers for both High and Elementary School pupils should be provided with a thermostatic valve which will regulate the temperature of the water automatically, but beside this, as has been said previously, there should be an attendant whenever the showers are used by Elementary School pupils.

Other adjuncts are toilets, a water fountain and an overflow trough which extends around the entire length of the tank, at the level of the surface of the water (Figs. 275, 276). Impurities that float on the surface are carried off by means of the overflow trough, and it serves as a cuspidor. It is very essential also to provide a sterilizer for the bathing suits. The water of swimming pools is to be considered from two stand points, *i.e.*, clearness and freedom from contamination. Filtration maintains the former and disinfectants the latter. Both bacterial and much gross organic matter accumulate such, as hair, threads, etc., not withstanding the most extreme care. It is practically impossible to keep water out of the swimmer's mouth, therefore it should come from a supply that is known to be safe and the pool must be kept scrupulously clean.

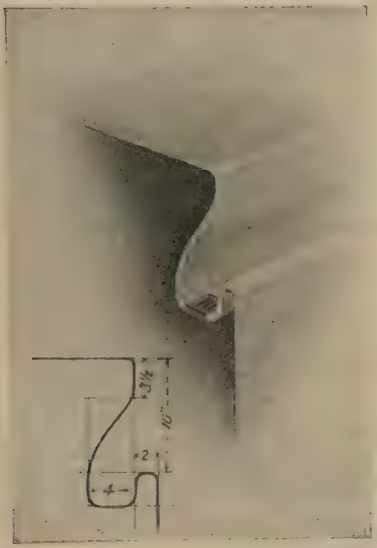

FIG. 275.—A very common design of Ceramic Mosaic scum gutter with a slightly protruding handrail of tile. (Swimming pools. The Associated Tile Manufactures, Beaver Falls, Pa.)

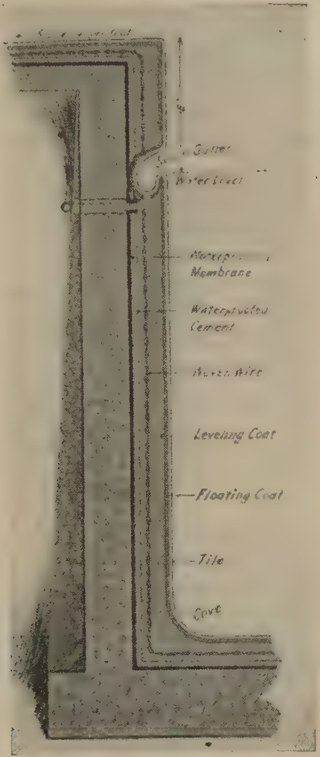

FIG. 276.—Typical cross section of reenforced concrete retaining wall for swimming pool, showing structural and waterproofing factors in diagrammatical form.

When the pool is emptied it can be thoroughly scrubbed, or a vacuum cleaner can be used. The simplest method of keeping the pool in a sanitary condition, of course, is to fill and empty it daily, but a constant flow of fresh water requires the consumption of 104 tons of coal per year in order to maintain the temperature at 70 degrees, or near it, which in ordinary school systems is prohibitive. A refiltration plant does away with this excessive cost and keeps the water clear.

The importance of continuous filtration is shown in tests of Minneapolis city water made before it was pumped into the swimming pool, when the number of bacteria per cubic centimeter was 14. After the first day's bathing without refiltration there were 1,400 bacteria per cubic centimeter.* Comparing the physical results of both unfiltered and filtered water with fresh city water, it was found that filtered water after three months' use was in better condition than unfiltered water after three days' use. A point of safety for the bathers can be well secured by one initial filtration and subsequent treatment with calcium hypochlorite, using a freshly filtered tank of water every week, or with refiltration and treatment using the same tank of water for several weeks. Alum is the agent by means of which filtration is secured. As it has sometimes been found passing through the filter, it has been advised to pump the water through a coagulation basin before it enters the filter, thus giving time for reaction, flocculation, and coagulation in particles large enough to clog the filter, and raise the efficiency from the beginning (Fig. 278). After the initial filtration it is important to operate the filter continuously, otherwise the plant itself sometimes produces a stench indicating that the tank has become septic. If there is to be an idle period of several hours, the filter should be washed before the pump is stopped, and treated with calcium hypochlorite (seven parts to one million), or some other equally good antiseptic.†

EFFECT OF TREATING THE FILTER WITH HYPOCHLORITE

	1 c.c. on Agar at 37°C.	1 c.c. on Gelatin at 20°C.
Before treating	2,500	30,000
½ min. after treating	35	3,750
3 min. after treating	10	1,250
10 min. after treating	20	325
30 min. after treating	0	0

The first sample was taken from the wash water at the beginning of the washing.

Most of the organisms found in swimming pools are saprophytic, but occasionally parasitic types are found. Of these the Bacillus coli and the typhoid bacillus are the most common.

There is not only an occasional organism such as those already mentioned but there have been epidemics of both simple and Neisserian vulvo-vaginitis, of conjunctivitis, of ear and throat infections and of ring-worm. These organisms are discharged from the body in perspiration and in small coherent masses of saliva, urine, feces, blood, mucus and pus, which are not easily dissociated, thus protecting them so that sunlight and drying have little effect. It is therefore necessary in selecting effective agents, to choose those that have strong oxidizing powers, such as the halogens or ozone, so that the mucus as well as the bacteria will be disintegrated.

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* Whittaker, H. A., Investigations on Swimming Pools at the University of Minnesota, Jour. A. M. A., lxx, No. 25, p. 1901.

† Stovall, W. D., and Nichols, M. S., Some Factors in Swimming Pool Control, Journal of Infectious Diseases, xxi (Nov., 1917), p. 484.

As an aid to filtration various agents have been used, ozone, the halogens, of which calcium hypochlorite is the best representative, ultra-violet light, electrocide, and copper sulphate. Of these ozone, violet light and calcium hypochlorite are by far the most important. Wallace A. Manheimer* reaches the following conclusion in regard to ozone and other substances used in the purification of swimming pools:

"Ozone when properly applied to the water of a swimming pool, effectively purifies the water. When one part of ozone per million parts of water is used, the result is sterile water. When half part ozone per million parts of water is used, a bacterial reduction of 99.8 per cent. results, except when too great an excess of air is introduced with the ozone. A study of the cost of operation of the ozonator has shown that a current consumption of two kilowatts per day with alternating current and of four kilowatts per day with direct current, plus one cent a day for calcium chloride, represents the total operating cost for a 60,000-gallon pool. This amounts to 11 to 15 cents a day for alternating current (at five to seven cents per kilowatt) and to 21 to 29 cents a day with direct current. The cost of refilling the pool is at least $30. The use of the ozonator decreases the number of times the pool must be emptied to such an extent that the cost of the installation is soon paid for. The application of ozone to the purification of swimming pools is automatic in control, reliable in action, and inexpensive in application. Accordingly, we recommend the considera-

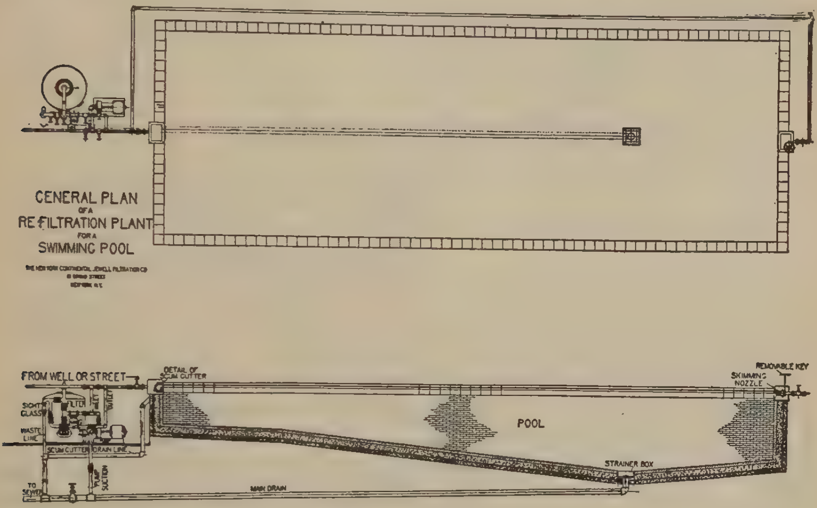

FIG. 277.—Swimming pool and filtration plant, Amer. Physical Education Review, vol. xx, No. 1.

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* The Application of Ozone to the Purification of Swimming Pools, Reprint No. 456 from the Public Health Reports (March 1, 1918), pp. 267–273); U. S. Public Health Service, Government Printing Office, Washington, D. C. (1918).

tion of this chemical as a standard procedure in the sanitary control of swimming pools."*

The manufacturers of the ultra-violet light claim excellent results with it. It is used in a number of especially well equipped pools and it is not cumbersome. It is, however, expensive.

If it is not feasible to install an ozone or ultra-violet light plant, the next best agent is calcium hypochlorite. The average amount of hypochlorite used is one-half part per million parts. Ordinary commercial hypochlorite of lime contains about 30 per cent. of available chlorine. On this basis a 100,000-gallon pool requires only one pound of treatment. The total annual cost of one treatment daily would be $7.30.† There are two objections to the use of calcium hypochlorite: first, its unpleasant odor when sprinkled on the water or thrown into the pool; second, a danger that the filter may be stopped if the lime sludge is thrown into the filter circuit. The lime, therefore, should be mixed with water in a pail, then filtered through cheese cloth into another pail, which in turn is dropped forcefully into the water, thus leaving very little of the chemical on the surface. There are also mechanical devices connected with the refiltration plant which automatically eject a hypochlorite solution into the tank. It has been found that a continuous flow of the solution is less efficient than a single daily dose.

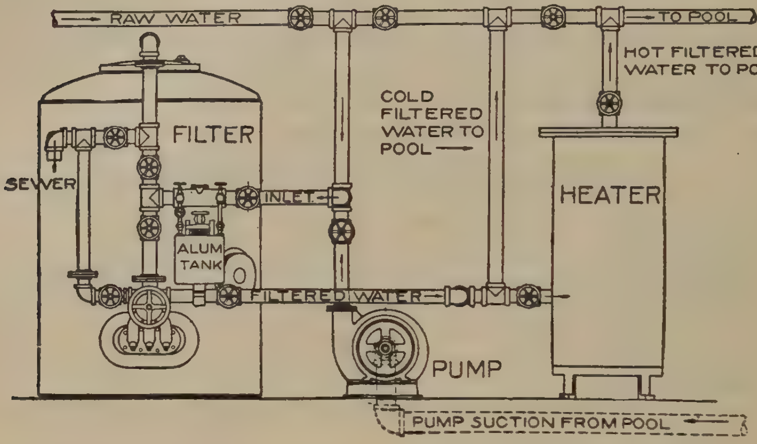

FIG. 278.—Approximate lay out for the re-filtration of a swimming pool. "Swimming Pools and Their Purification." Stricker, F. D., M. D., Amer. Physical Education Review vol. xx, No. 1 (Jan., 1915), pp. 11–14.

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* See also Manheimer, Wallace, A., Reliability of Ozone in Swimming Pool Disinfection, Jour. A. M. A., lxx, No. 26 (June 29, 1918), p. 1991.

† Crane, A. M., The Safeguarding and Care of the Indoor Pool, American Physical Education Review, xx, No. 1 (Jan., 1915), pp. 1–8. See also Manheimer, W. A., Methods for Disinfecting Swimming Pools, American Physical Education Review, xxii (Jan., 1917), p. 221.

In guarding the public against infection from swimming pools it is helpful to recognize the fact that the amount of water in the pool, the number of swimmers, and the variation in personal cleanliness and attire are great factors in determining the number of bacteria, as well as the necessity of closely watching the conduct of the swimmers while in the shower room and after entrance into the water.

Summary of Basic Principles for Pools and Swimmers*

1. Maintain the water in the pool pure and clear, employing both refiltration and chemical disinfection.
2. Have the pool well lighted; natural light by day, sunlight if possible.
3. Keep an attendant always on duty when the pool is in use. Prohibit admission at other times; allow no one to enter the pool alone.
4. Maintain a strict supervision of the bathers, medical examination if practicable, preventing persons with communicable diseases, such as purulent conjunctivitis, sinus trouble, vaginitis, impetigo, ringworm, otitis media, and infected tonsils from entering the pool.
5. Enforce the scrubbing of each bather with the use of soap before entering pool.
6. Prohibit all clothing (boys), or provide sterilized clothing.
7. Surround the pool with an overflow trough, and prevent pollution of any kind in or about the pool.
8. Prevent visitors carrying dirt and disease germs on their footwear into the pool room.
9. Do not have any obstruction in the pool, nor along the edge of the pool, nor adjacent to it.
10. The water in the pool is purified and is safe for bathing purposes, but is not a drinking water; therefore bathers are warned against swallowing any pool water taken into the mouth.

In the Elementary Schools of Cleveland it was found that 88 per cent. of girls and 45 per cent. of boys over eight years of age could not swim; and that 77 per cent. of girls and 34 per cent. of boys in high school could not swim. Dr. Peterson estimated that to make swimmers of 18,500 boys and girls in Cleveland's fifth and sixth grades it would be necessary to furnish twelve or fourteen pools. Each boy and girl would require six lessons.

It is desirable to teach swimming after school and Saturdays. With two lessons given after school and three on Saturdays, with 25 pupils in the tank at each lesson, this large number can be made proficient in swimming.†

Methods of swimming are clearly stated in an article entitled "Swimming in the Elementary Schools," E. B. Koch, Amer. Phys. Educ. Review, Jan., 1915.

No one should enter the pool within an hour after eating. The average length of swimming periods is a half hour. For delicate children 15 or 20 minutes is ample, and in some instances too long. If the child's teeth chatter and the lips are blue, especially if unusual signs of fatigue are manifested the following day, swimming should be postponed until enough vigor has been developed to make a quick reaction to water at 70 degrees possible. After the period, the body should be showered first with warm water followed by cold, with a vigorous rub at the end.

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* Crane, A. M., The Safeguarding and Care of the Indoor Swimming Pool, American Phys. Ed. Review (Jan., 1915).

† Peterson, E. A., To What Extent Should the Board of Education Furnish Facilities for the Teaching and Practice of Swimming? Amer. Phys. Ed. Review, News Notes (May, 1917).

The value of swimming exercises may be summarized as follows:

1. It allows a maximum amount of exercise with a minimum strain on the heart, because the body is in a horizontal position.

2. Swimming on the back is a very good corrective exercise for round shoulders and hollow chest.

3. The leg exercises assist in overcoming constipation.

4. All the large muscle groups are brought into play as in no other form of exercise.

VACATION SCHOOL

The first vacation school experiment was made in 1878 by a clergyman named Bion in Switzerland. This movement began in Chicago in 1896 and has since spread to other cities in the United States. It is so popular that applications for membership far out distance accommodations.*

In the slums of large cities school authorities are practically forced to keep open school during the vacation as Juvenile Court records show increased activity during the summer months. Children are much happier in school and certainly much safer morally than when left to their own direction on the streets. Vacation schools provide a minimum of the usual school activities substituting art, basketry, manual training and woodcraft, dramatics, gardening, nature study, physical training, swimming, and expeditions to near country places or parks, etc. The summer school is a most excellent place to provide study derived from objective projects which give the child constructive material based upon activities presenting endless interest (see article on the Kindergarten).

The country outing movement is extremely important in furnishing a healthful change of environment for all city children living in congested districts. Children are taken to homes in rural communities or to large camps in the country where they stay from two to four weeks.

Studies by Ellsworth Huntington of Yale University in the relative efficiency of work among factory employees and college students during different months of the year show that industrial and intellectual production is at its lowest during the last weeks of January and during February and March.† The open air school at Charlottenburg near

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* Kingsley and Dresslar, Open Air Schools, Bulletin No. 23 (1916), Department of the Interior, Bureau of Education, Washington, D. C.

† Norbury, F. B., The Mechanism of Exhaustion, Illinois State Medical Journal, xxviii, No. 1 (July, 1915).

Berlin has adopted the months of January, February, and March as their vacation period, doubtless for reasons of economy and adaptability to inclement weather.

If further studies show this to be a general biological fact, midwinter vacations may eventually be delayed until January and then prolonged, and summer vacations shortened, with benefit to the entire school community.

VACATION CAMPS

Vacation Camps can be found in all quarters of the United States. They are rapidly becoming popular and justly so, because if properly conducted they not only afford "life in the open" but an opportunity to achieve. At the present time 500,000 boys in the United States visit vacation camps in the summer.

"Essentials for a good camp are good drinking water, a body of water for aquatics and fishing, a body of woods for roaming, hunting and wood construction, an open field, sleeping accommodations, tents, cabins, good drainage, proper sanitary equipment, beauty of location, seclusion which allows a free dress and manner of living, discipline, allotments of labor, privilege and freedom, camp fire, good food and plenty of it, suitable clothing with which to rough it and be comfortable, communication with civilization, sufficient rest, and enough interests."*

The more elaborately equipped boys' camp provides athletics including baseball, indoor baseball, tennis, track athletics, volley ball, etc.; water sports including swimming, water games, rowing, canoeing, etc.; canoe, camping and fishing trips which last several days and manual training, wood craft, photography, first aid, music, tree clubs, and tutoring if desired. The girls' camp provides horseback riding, bowling, archery, candy making, nature study, and corrective gymnastics, besides some of the more vigorous activities of the boys.

Both Forbush and Ernest Thompson Seton have taken groups of boys into the woods with very little equipment except a few tools and the minimum of provisions. It makes boys much more self reliant and observing if they are thrown upon their own resources. Boys and girls who have had the splendid training afforded by the Boy Scout and Camp Fire Girls movements are already trained to get the best of such summer expeditions. J. E. Russell, Dean of Teachers College, Columbia University,† regards the Boy Scout movement as the greatest educational agency in the world.

In Germany, children are taken in small groups on vacation "hikes" which are thought to be even more beneficial than camp life.‡ Probably the most important feature of camp life and of the various out-door organizations under consideration is the personnel of the teachers, especially of the men and older boys who have charge of the small units of which the group is composed. The character of one fine young fellow with some of "the hero" in him often changes the entire conduct and point of view of his unstable, immature charges.

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*Robinson, E. M., Y. M. C. A., in Forbush ("Play").

† Teachers College Record (1917).

‡ Selter, H., "Gesundheitspflege des Kindes," Kruse und Selter.

SCHOOL KINDERGARTENS OR VORSCHULE

These are special schools which provide means for building up the health of the anemic, rhachitic, scoliotic, poorly nourished and underdeveloped children who are presented for the first time for school entrance. Methods of life are revolutionized upon school entrance, confinement being substituted for freedom, and intensive social relationships for a relatively isolated environment. Therefore it is found that most delicate children lose weight, height and muscular development during the first year of school life.* It has also been found that there is considerable relative increase in sickness during this year.

The proportion of children requiring the care of the school Kindergarten is approximately 10 per cent. Of this number there are 58.5 per cent. anemic, 9.0 per cent. poorly nourished, 60.0 per cent. rhachitic, 24.5 per cent. scrofulous.†

Without such care, children excluded from school return to unhygienic homes, thus still further increasing ill health and retardation.

The gain from care in these schools is most gratifying. There is an increase in weight of from 2.9 to 3.15 kg., and in height an average increase of 10.5 cm. (Kruse und Selter).

The equipment is practically that of a Kindergarten Open Air School with sand piles and gardens and ample out-door space for play with quarters for daily rest. Bread and milk is furnished in liberal quantities and is an important item in the improvement secured. Children are not kept over night but remain in school from an early morning hour to late afternoon.

"If the hygienist could have his way the first year or two of school life would be a Vorschule, in which the teachers would be hygienists; and the aim for this year would be to determine the child's stage of development, his physical resources, his physical defects and as far as possible to remedy these defects."‡

SUMMER COLONY SCHOOLS

Summer colony schools were started in Italy in 1853. This was really the first open air experiment. At present many types of open air schools are carried on there. Italy has the great disadvantage of old unhygienic school buildings. To compensate for this she has a mild and beautiful climate of which her educators take advantage. "A folding portable combined desk and chair has been the special feature of the Italian contribution to the successful handling of the open air school problem."* This makes teaching possible anywhere, indoors or out of doors. Journeys of some length are taken and the class rests whenever desirable. From this fact some of the schools are called "Traveling Open Air Schools."

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* Schmidt Monnard in H. Selter, "Handbuch der Schul-hygiene," Dresden, Steinkopf (1914), p. 362; Aurisfeld in H. Selter, "Handbuch der Schul-hygiene," Dresden, Steinkopf (1914), p. 363.

† Kruse und Selter, "Gesundheitspflege des Kindes," pp. 320–321.

‡ Burnham, W. H., A Health Examination at School Entrance, Journal American Medical Association, lxviii, No. 12 (March 24, 1917).

Years before the day of the open air school in France, "Grancher had put into operation his splendid plan of preserving the seed corn of the nation by sending the delicate children of the tuberculous poor into families of healthy peasant stock."† The first open air school in France was founded in 1904 at the entrance of the forest of Fontainebleau for children from the slums of Paris. This was under private auspices.

OPEN AIR SCHOOL

The Forest School is not for children with open tuberculosis but for mild cases of closed tuberculosis and for children suffering with anemia, malnutrition, rickets, convalescent chorea and milder forms of nervousness.

The first forest school of considerable size and distinction was located at Charlottenburg near Berlin. The movement elicited the combined efforts of at least half a dozen municipal and private agencies and many individuals and in 1904 the school was opened. It has been a great success and a model for many other open air schools. In 1907 England launched an experimental open air school in Bostall Wood near London, and in 1911 the United Kingdom set aside $500,000 for grants to sanitarium schools for children suffering from pulmonary or surgical tuberculosis. England provides open air school facilities which vary to meet the needs of different types of delicate or sick children. One type of residential sanitarium open air school accommodates cases of pulmonary tuberculosis, another surgical tuberculosis, still another delicate children. Six or more open air day schools are provided for light cases of pulmonary tuberculosis, eleven or more for delicate children. Besides this there is a strong movement for open window schools and for play ground classes for normal children both in the city and in the country.

In the United States, Providence in 1908 was the first city to adopt open air methods of education for its delicate children. In 1909 Chicago established an open air school on the roof of Mary Crane Nursery in a densely populated and poverty stricken district. This school, is in the Hull House group of buildings.

Open window rooms supplied with additional steam coils by means of which the room temperature is maintained at 60° or 65° have been substituted for open air rooms in Chicago.

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* Upton, S. M. H., Open Air Schools, Teachers' College Record (May, 1914).

† Kinsley, S. C. and Dresslar, F. B., Open Air Schools, Bureau of Education, Washington, Bulletin No. 23 (1916).

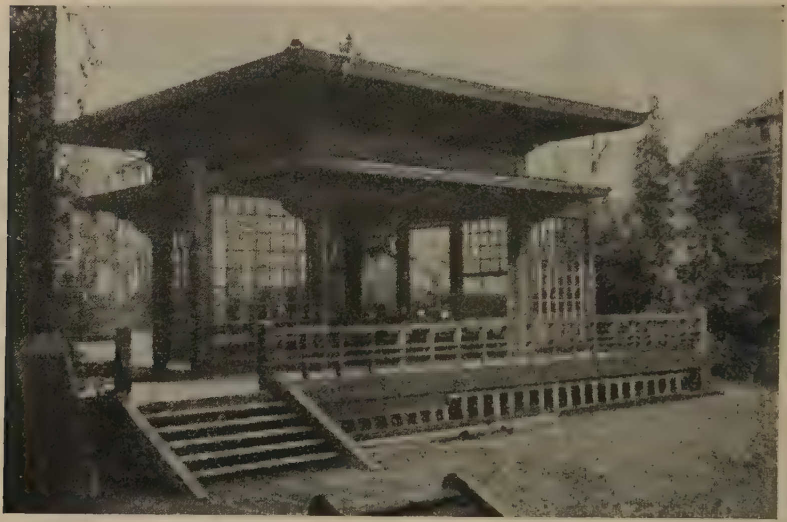

Fig. 279.—One of Japanese open air classrooms. (Phoebe Anna Thorne School, Bryn Mawr College.)

Delicate children in the United States are cared for in two kinds of open air schools.

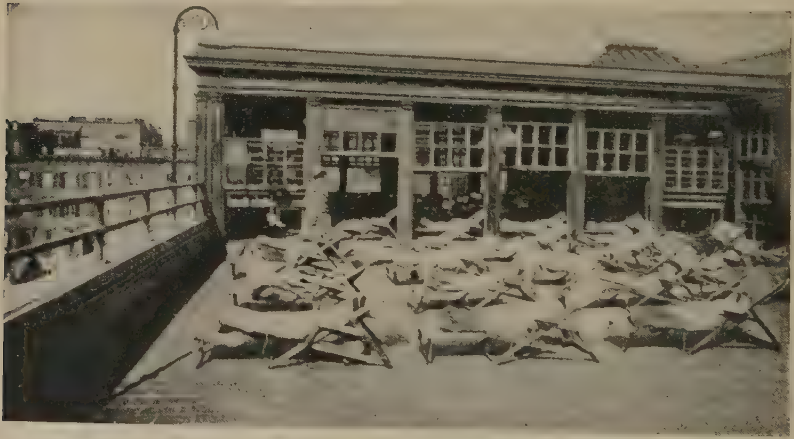

Fig. 280.—Outdoor classroom on roof of public bath building in New York, showing ordinary windows made with three sashes.

First, schools which are located entirely out of doors, *i.e.*, in shacks, as in Springfield, Massachusetts; in finely constructed buildings as in the Phoebe Anna Thorne Open Air Model School for Girls, Bryn Mawr, Pennsylvania (Fig. 279); in tents as in Baltimore, on the roofs of school buildings as in the Horace Mann School, New York City (Fig. 290); on roofs of public bath houses as in Chicago, and in discarded ferry boats as on the East River, New York City.

Second, open air rooms located in school buildings (Fig. 283). These are found in almost all large cities.

European municipalities have placed such schools in the forests wherever possible. Thus far the United States has been contented with open air facilities in congested districts.

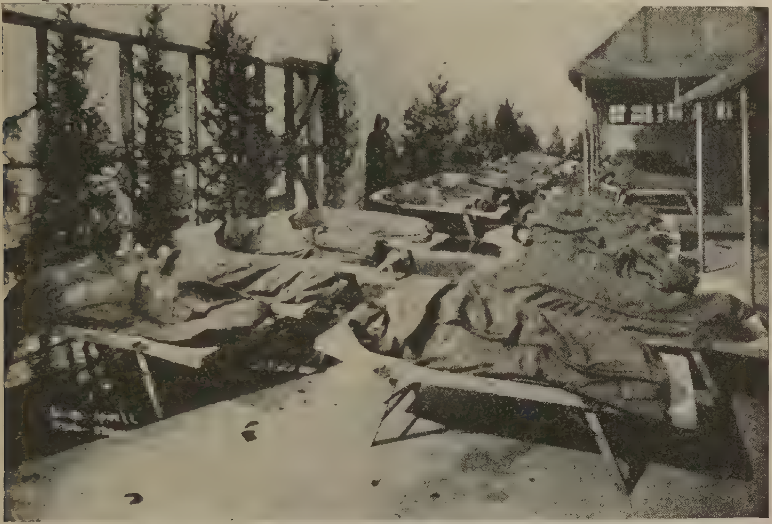

Fig. 281.—Rest period, Elizabeth McCormick Open-air School on the roof. (S. C. Kingsley, in "Journal of Out-Door Life," 1916.)

Sites for Open Air Schools.—Ideally, a natural forest in some accessible place, yet out of the main currents of modern life, offers the best situation for schools of this character. Naturally the problem of transportation must be met if such sites are to be utilized. Hill tops, low, dark, poorly drained valleys, ungrassed dusty districts are to be avoided.

The main features are the following:* Class rooms are situated preferably on the east or west sides of the building. The rest room on the south, kitchen, dining room, showers, doctor's office, and toilets on the north.

Desks should be placed so that the light may be received from the left. Chairs should have solid backs to protect the children's backs from the cold. In the Phoebe Anna Thorne School at Bryn Mawr the seats and backs of the chairs have twice the usual width. Most open air schools have portable furniture. Children in the Ethical Culture open air classes frequently shift their chairs from one part of the roof to the other, depending upon the sun, wind or rain. Children should be exposed to the direct rays of the sun as far as possible, care being taken to protect their eyes though it has been shown that eyesight does not suffer injury in open air schools.*

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* For description of architectural plans see Kingsley and Dresslar, Open Air School, Bureau of Education, Washington, D. C., Bulletin No. 23 (1916).

FIG. 282.—"For we have fresh air that gives us cheeks like the rose." Elizabeth McCormick Open-air School. (S. C. Kingsley, in "Journal of Out-Door Life," 1916.)

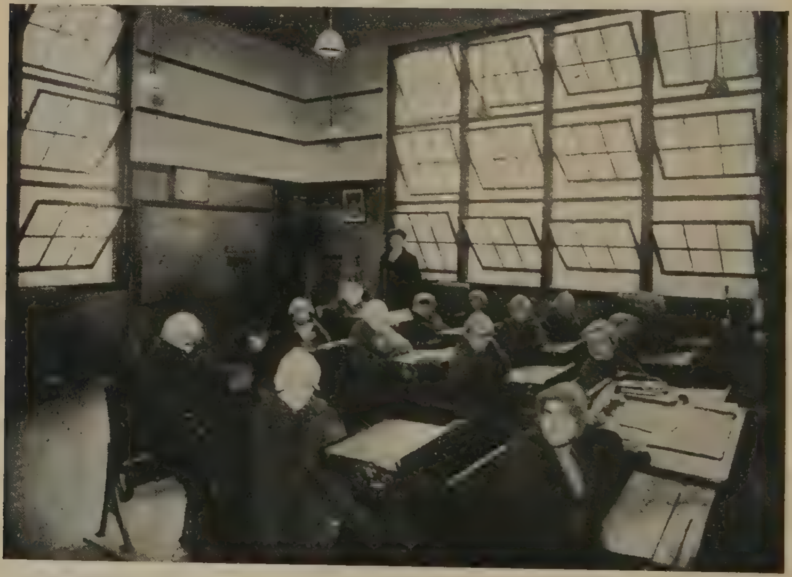

FIG. 283.—Type of fresh-air room required in all new school buildings in New York City. The windows open and close on ratchets and are easily controlled.

Heating.—The aim should be to keep the room temperature about 50 degrees or between 50 and 60 degrees. Man's greatest mental efficiency is maintained at a temperature of 38 degrees his greatest physical efficiency at 60 degrees.* Low temperatures give the best results if children are warmly dressed and well fed. If heat is introduced, care must be taken to keep the windows open and the air fresh.

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* Teachers' College Record (May, 1914), p. 32.

The heating and ventilation of open air rooms depend upon the window equipment of the room. If windows are confined to one side they may be fully opened and yet afford very poor ventilation when the wind is on the windward side. Cross ventilation occurs when windows are opened on opposite sides. There is usually an effort to avoid this on account of drafts. Windows of two or three adjoining sides may be opened beneficially where the wind is not too strong. If air enters the open air room from windows on only one side in a school otherwise using the plenum system, cross ventilation disturbing the rest of the school may be avoided by placing a reheating radiator in the wall of the open air room at the base of the incoming flue. As the resistance of the ducts at the base of the flue just before it enters the room is much reduced when the heated air rises from the wall radiator into the room, it happens that even if the windows are opened, very little if any effect on other rooms is communicated back through the flues, heaters, etc., because the pressure on the main duct is maintained at a higher point. Of course, continuous suction of foul air occurs at the outgoing duct.†

The best windows for open window rooms are in three sections with horizontal pivots. By this type of window, entering air can be directed upward and the quantity controlled. Windows are also placed in the roof of the Horace Mann School, providing more sunlight.

The floor is an important feature in open air rooms as the children's feet may become so cold as to endanger their health. Floors should be of wood, covered with linoleum and the sides of the room should be boarded in to a height of 3 feet.

Equipment.—Most open air schools provide sleeping facilities for a nap at noon time. The best cots are those in use by the Elizabeth McCormick Memorial Fund. They are 5 feet 2 inches long and 28 inches wide, reinforced by strips of heavy canvas across the points of greatest wear and at the corners. They can be folded at the head and foot into a compact form so that they can be easily stored.

Clothing.—The home clothing worn by children in open air rooms should be largely of wool. Heavy extra sweaters should be provided and toboggan caps. An "Eskimo outfit" is obtainable which consists of a two-piece pajama suit with hood, made of heavy blankets, 70 × 80 inches in size. The Horace Mann School has adopted "The Parka" —a long-hooded coat made of very closely woven khaki. This is very light and pliable and is wind proof. The children wear a lumberman's boot or a fleece lined, sheepskin boot. Sitting out bags are made of heavy blankets and are protection against cold feet. Boxes filled with straw for the feet also afford some protection against the cold. Warm gloves should be worn even while writing as cold hands are a menace to health.

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* Norbury, Frank P., Illinois State Medical Journal, xxviii, No. 1 (July, 1915), p. 4.

† Lewis, Samuel, unpublished notes. Courtesy of Mr. Dwight H. Perkins, Chicago. See section on School Ventilation.

For cost of the outfit apply to the Elizabeth McCormick Fund, Chicago. It includes the cap, sweater, gloves, Eskimo outfit, over boots, sitting out bag, sleeping bag, sleeping cot, two Turkish towels, (if shower baths are given), tooth brush, comb, hair brush, nail-file and thermometer, kitchen and dining room furniture, scales for weighing the children, etc. For the cost of separate items consult also Kingsley and Dresslar, Bureau of Education, Bulletin No. 23 (1916), "Open Air Schools."*

Economic Conditions of Pupils.—Of 620 open air school children in different cities 42 per cent. were diagnosed as tubercular and 52 per cent. were suffering from anemia and malnutrition. A study made in the years 1913–14 (funds to parents department of the Cook County Illinois Juvenile Courts) concluded that an income of $875.00 per year was necessary to maintain a family of five or six in a state of physical and moral efficiency. (It is nearer $2000 per year at the present time.) A questionnaire sent by the Bureau of Education to Open Air Schools in 1913 shows that 38.7 per cent. of 371 Chicago families had an income of less than $75.00 per month and that the average number of pounds below weight was 8.66 per child.†

Lunches.—It has been found that the poor suffer from a lack of protein and fat and that the average ration of school children at home in an Italian district is 450 calories. It is calculated therefore that in order to bring the food supply up to normal, 1,000 calories must be supplied through the day at school, half of this being fats and proteins. In most schools there is a morning lunch consisting of cereal or bread and jelly and milk and a noon dinner of meat, potatoes, one vegetable, bread, milk and a simple dessert. The average individual cost for large groups is 14 to 15 cents per day (see section on school feeding, p. 928). I. O. Woodruff‡ found that children in open air schools gained without extra feeding, probably due to an increase of appetite.

Health Precautions.—Anemic and poorly nourished children chill easily. This must be overcome either by external heat or by gymnastic exercise. If a cold child is allowed to go into a warm room for a few minutes his extra outdoor clothing should be removed, otherwise he may develop bronchitis. Foot warmers and soap stones are harmful. Gymnastic exercises of special value here are story plays involving deep breathing, arm and leg throwing.§ Children of the poor who have coffee and alcoholic drinks at home, fare badly in open air schools. There is an alarming pulse rate, fever, sleeplessness and restlessness.

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* Ayres, L. P., "Open Air Schools."

† Kingsley and Dresslar, "Open Air Schools."

‡ Fresh Air Schools in New York City, Fourth International Congress of School Hygiene, p. 80.

§ See Physical Training for the City Schools of Michigan, Teachers' College Record (May, 1914), etc.

The education of the mothers in regard to these matters therefore becomes imperative.

Colds contracted by open air children are severe and prolonged. Thin clothing, constipation, exposure to cold after a hot bath, inactive skins from infrequent bathing and sleep in unventilated rooms, all predispose to colds. Adenoids and enlarged tonsils are more significant under open air conditions. It is said that singing in the open air injures the throat.

Health Observations.—The most rapid gain occurs in the first month. A disproportionate increase continues, however. The gain in hemoglobin is lost after the first increase, this being true both in open air and artificially ventilated schools.

Health Supervision.—(See section on medical examination, pp. 919–927.) Medical examinations complete or partial are conducted four times a year in the open air schools and include the usual items; adenoids, tonsils, glands, etc., with the addition of weight, height, per cent. of hemoglobin, and examination of the chest stripped, with especial thought of the possibility of tuberculosis. The von Pirquet tuberculin test is used in doubtful cases and not infrequently it is repeated. Weight and body temperature in these cases are carefully watched and recorded. Physical defects thus found are followed up by the nurse and rectified.

The children are selected by the medical supervisor who inspects class rooms and chooses from them suspect tuberculosis cases, choreics or children nervously unstable, children who have a record of many absences from ill health and anemic and poorly nourished children.

The daily routine of the medical inspector begins at 9:30 after the nurse has recorded temperatures, the pulse, and respiration. His duties are:

1. Conference with the principal on all questions that have a bearing on health, including absences, transfers, complaints, etc.
2. Conference with the nurse in regard to new developments.
3. Examination of children suspected of having infectious diseases. Throat cultures if necessary.
4. Conference with the teachers concerning indifferent or irritable children.
5. Oversight of ventilation, temperature, odors, etc.
6. Inspection of thermostats and outlet ducts.
7. Oversight of clothing as to the amount in relation to the weather.
8. Recommendations for children with fever, for fatigue, for colds (isolation and rest).
9. Recommendations for the amount of school work and general routine.

The school nurse notes all the above conditions and reports to the physician all home conditions that have a bearing on the case.

The teacher notes temperature, ventilation, the adjustment of windows and screens, the clothing of the children in relation to cold and dampness, and all symptoms which may be produced by physical defects or infectious and personal habits.

With a very few exceptions experimenters with open air and open window schools are satisfied as to their value. D. C. Bliss of Montclair, N. J. (Pedagogical Seminary), however, made a study of the height, weight, fatigue, and number of absences of children in open window and control groups and found that the children of the control groups made more consistent gains, were absent very much less and showed no more fatigue than children in the open window rooms. He attributes it partially to the excellent ventilation installed in the Montclair schools. The foreign, the New York, and the Chicago experiments showed a marked difference in result in the two types. An interesting and careful study by Dr. S. Josephine Baker* on "Class Room Ventilation of Respiratory Diseases among School Children" was undertaken with 5,533 pupils in 76 class rooms in 12 schools, operated under three types: (*A*) Cold (50 to 60°F.) open window class room, ventilated by natural means. (B) Moderate temperature (60 to 70°F. averaging 68°F.), ventilation wholly by open window. Some rooms with gravity exhaust ducts, some not. Window reflectors used. (*C*) Temperature averaging 68°F., ventilation by plenum fan, windows closed. Her conclusions were: (1) That with plenum ventilation (type *C*) the rate of *absences* from respiratory diseases was 32 per cent. higher than in type *B* with open windows and 40 per cent. higher than in type *A* with open windows and a temperature of 60 degrees or less. In type *C*, the rate of respiratory diseases among pupils in *attendance* was 98 per cent. higher than in the open window (type *B*) and 70 per cent. higher than in type *A*.

Many of the school architects are looking forward to the day when most of the school work will be done in the open air. Teachers are a unit in testifying to the increased alertness and freedom from fatigue and disorder, finding it a benefit to themselves as well as to the children. In view of the Montclair experiment final conclusions can not be drawn until more control experiments of a similar nature are made because the general advantage of small groups, rest, extra feeding and freedom, without fresh air may produce similar results.

SUMMARY

Until the last five years stress in school hygiene, even under the most auspicious circumstances, has been placed upon the prevention of communicable disease, with more or less desultory physical examination. As the field stands in review there are some phases which appear to be particularly constructive and indicators of future advance:

1. The correction of physical defect, especially as it relates to focal infection and the conservation of vision.
2. Nutritional diagnosis and treatment.

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* Bureau of Child Hygiene, Department of Health, New York City, Reprint Series No. 68 (Feb., 1918).

3. Training in hygiene, physical habits—such as the care of the teeth, hours of sleep, cleanliness, open windows, posture, etc.
4. Training in economic and productive mental habits.
5. Training in physical education.

Among older children, the secret of success depends upon the ability of the teacher to secure coöperation. If the intelligence of the child is evoked, if he sees his problem as a social problem, if an appeal is made to his responsibility, if he himself becomes a health teacher—if he is consciously such—then it becomes a matter simply of holding him back. He will be enthusiastic about his own hygiene, and quite possibly somewhat too aggressive in regard to the hygiene of his neighbor. Among younger children school nurses, dental hygienists, and nutritional workers are accomplishing great things, and are doing it by charting the individual child's progress, by drilling him in personal health habits, by health exhibits in which he has an important part, by making him a monitor of room temperature, of school mats, of school yards, school sidewalks, and of school dust—in short, by applying the great educational principle of John Dewey, "Learning by Doing."

CHAPTER IX

HYGIENE OF INFANTS IN GENERAL

By Walter Reeve Ramsey, M.D.

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Prenatal Care. Protection of Mother and Fetus During the Period of Gestation.—The old idea that the life of the child begins at birth and that its physical and mental development dates from that period is no longer tenable.

The relation between mother and fetus is so intimate during intrauterine life that the future of the infant, is often decided during the first months of pregnancy. This interdependent relation continues not only until the birth of the child, but in a measure during the period of lactation.

It is a question, therefore, of great moment how far improper nutrition, illness, body defects, occupation, etc., of the mother are capable of influencing the proper development of the fetus.

It is difficult, in most cases impossible, to determine with any degree of accuracy the effects of these influences. The most that can be done is to take certain influences, the effects of which can be accurately measured, and then base our opinion upon them by analogy.

A consideration of the hygiene of the infant should extend far ahead of the beginning of fetal life and might properly include the life history of the parents and grandparents.

It should be apparent that the least that can be taken for granted, is that both the father and the mother be healthy individuals in the broadest sense of the term in order to have a fetus develop normally and that after conception, the health of the mother be maintained at as high a point as possible.

So many factors enter into the question of what is normal and what abnormal, particularly as concerns the environment, food, occupation, mental attitude, etc., of the mother that it is difficult to be arbitrary in deciding them, as it not infrequently happens that what would be normal for one woman would, under other conditions, be abnormal for another. We shall, therefore, discuss the known conditions relative to the mother, which directly affect the fetus, and in as far as possible in the order of their frequency and importance.

Improper Nutrition.—By this is meant a condition in which, without any definite pathological entity, the general physical status is below par. The woman is pale; hemoglobin below normal; the muscles flabby. She is easily fatigued, and not infrequently there is also an accompanying mental depression.

This condition of malnutrition not infrequently exists before conception and naturally with the added demand upon the system will, if not corrected, grow progressively worse.

The causes of malnutrition in the mother are usually not difficult to determine.

One of the most common causes of malnutrition in the young married woman may be found in the festivities of the prenuptial period. Excitement, over fatigue, loss of sleep, improper and excessive food frequently lay a proper foundation for a period of invalidism throughout the gestation period.

Food.—Improper and insufficient food is one of the most common causes of malnutrition. This is true particularly among the working classes, where the girls work in factories up to the time of their marriage and where there is lack of knowledge of food values and food preparation.

That a course in food values and food preparation should be given to the girls of every upper grade school there is not the faintest doubt.

During the entire period of gestation, proper food and proper elimination go hand in hand. It is not only necessary that proper food and sufficient food should be eaten, but the proportion and character of the food must vary in the individual case.

Sufficient amounts of coarse food, such as vegetables and coarse bread, should be eaten to keep the bowels regular and free. Constipation, and the consequent autointoxication attending it, are undoubtedly fertile causes of malnutrition in the pregnant woman. Further elimination of waste products should be increased by proper amounts of water, drunk preferably between meals.

Excessive meat should be avoided as it tends to derange the digestion and greatly increases the elimination of nitrogen.

Alcohol should be excluded from the diet of pregnant women and coffee and even strong tea should be drunk sparingly.

Housing.—Bad housing conditions is another fertile field for the production of malnutrition. The home of the prospective mother should be comfortable, sunny and well ventilated. Sleeping in small rooms with the windows and doors closed, resulting in improper areation of the blood from bad air, cannot fail to have a deleterious effect upon the fetus.

Occupation.—Occupation is an important factor in the nutrition of the mother and fetus.

In my work in France among the women and children I found that when the women worked in factories up to, or nearly up to, the time of their confinement, the mortality among the infants often reached 50 per cent. in the first weeks. It was found that when the women lived in the country and worked in the homes, or on the farms, the mortality among the infants during the first weeks was scarcely above 85 per 1,000 births, although the work was perhaps quite as hard, and the sanitary conditions under which they lived were quite on a par with those in the city.

If these women were taken out of the factories a month before their confinement and given proper rest and good food, their physical condition improved rapidly, with the result that the babies were born vigorous, the mothers were able to nurse them, and the mortality was reduced to a minimum.

The most ideal occupation for a pregnant woman is the ordinary duties of the household. She should perform her duties leisurely and should not be on her feet but a limited part of the time. She should spend an hour or two during the middle of the day in the recumbent position, and during the last weeks it may be necessary, if there is much disturbance of the venous circulation in the lower extremities (varicose veins), to spend much of the day in a sitting posture with the feet elevated.

Occupations which necessitate long periods being passed in standing or even sitting in cramped positions or where the air is charged with foreign substances which act as an irritant to the respiratory tract should absolutely be prohibited.

On general principles the state should prohibit pregnant women from working in factories except under the most favorable conditions.

It would be much better to give women, where they are dependent, sufficient pension to keep them in the home and proper employment should be furnished for them there.

Exercise.—Exercise is, however, of vital importance to the health of both the prospective mother and fetus and should be maintained up to the last days, whenever possible. Riding about in an automobile does not take the place of walking.

Mental Condition.—The mental condition of the pregnant woman probably exercises some influence upon the well being of the fetus. Just how much there is, if anything, in Maternal Impressions it is impossible to say. It would seem logical, however, that in the interest of both, the mental condition of the prospective mother should be tranquil and happy. She should avoid exciting plays and literature, and coitus should be avoided during the first and last months of pregnancy.

Physical Defects.—Many of the conditions which result in injury and death to the fetus are frequently directly dependent upon physical defects in the mother. Of these perhaps the most common are those of malformations and malpositions of the uterus. Malposition of the uterus, particularly retroversion, is a common cause of abortion in the early months of pregnancy.

Malformations of the uterus, such as bifurcation, are not rare and often result in the expulsion of the fetus before term.

Deformities of the pelvis as the result of rachitis and tuberculosis are perhaps the most common causes of injury and death to the fetus during parturition.

Changes in the normal diameter of the pelvic ring are not so necessarily fatal to the fetus since the technique of Cesarean section has been perfected, together with other surgical technique now practiced by skilled obstetricians. These operations result in the saving of a majority of infants who were formerly sacrificed.

Tight lacing, thereby deforming the chest wall and crowding the abdominal organs out of their proper positions is still a source of danger to the fetus, but certainly whatever other delusions women may have regarding dress this one fortunately seems to have passed, at least for the time being, and we hope for ever.

Illness.—All forms of illness, both acute and chronic, react more or less directly upon the fetus. Many of the acute contagious diseases such as Diphtheria, Scarlet Fever, and Measles, may run their course and recovery of the mother take place without any apparent injury to the fetus. Abortion, however, is common and if the disease is at all severe the fetus is liable to show the results later even if it is not apparent at birth.

Such diseases as whooping cough are particularly liable to produce abortion and the experience with the recent epidemic of Influenza (Flu) has demonstrated it to be most fatal both to mother and fetus.

Exposure to all contagious diseases should, therefore, be carefully avoided by pregnant women. They are particularly liable to infection and if infected, they run great chances of paying the penalty with their lives, or at least with the life or normal development of the unborn child.

Any inflammation of the uterus or tubes (metritis, endometritis, salpingitis, ovaritis) is apt to injure the fetus in some manner and expulsion is liable to occur before term. The one disease, however, which is responsible for more injury to the fetus and for more still births and abortions, as well as constitutional defects following birth at full term, than any other is syphilis.

Another common condition often interfering seriously with the nutrition, and sometimes the life of the fetus, is the persistent vomiting of pregnancy. It is not an infrequent occurrence that this condition is allowed to go on for months without treatment, the family believing that there is nothing to be done.

Uremia is another frequent source of injury or loss of life to both mother and fetus. The uremia may result from over taxation of the kidneys which are already diseased, or perhaps more frequently from an acute nephritis resulting from an over-taxation of the kidneys by toxic substances.

The urine of pregnant women should be examined regularly at least once monthly during the entire period of gestation and should continue to be examined daily for a considerable period after confinement as uremia not infrequently follows some days, or even weeks, after delivery.

Abortion.—There are certain conditions which definitely predispose to abortion. There are, however, many other conditions which are responsible, directly or indirectly, for the death or expulsion of the fetus before term which are impossible to determine.

Ohlfield assumes that 20 per cent. of all pregnancies end in a premature expulsion of the fetus. It is probable that in a large number of cases the fetus is expelled in from one to three weeks or during the following menstruation, and this without the knowledge of anyone. This may occur with, or without, the intervention of anyone in a criminal manner. As to the frequency of abortion the following table has been prepared by Agnes Bluhm, in 100 cases:

3.34 during the first month
25.94 during the second month
43.51 during the third month
14.64 during the fourth month
6.69 during the fifth month

From this it would seem, as has been generally believed, that the third month is particularly favorable for abortion. It is the general experience among physicians that after the third month the pregnancy is more liable to continue to term.

Of all illnesses which affect the mother, syphilis is by far the most frequent cause of abortion. With the Wassermann reaction and the early possibility of treatment the record for miscarriages becomes less and less, with a fair chance of a normal and apparently healthy fetus.

Other illnesses which frequently produce abortion are Malaria pneumonia, colitis, etc.

Many abortions are produced by mechanical means, hard muscular work, in which there is much body motion and jarring.

In 100 confinements in workers, Hirchberg found 9 premature births in sewing women, 12 in stone cutters and 16 in washerwomen.

Cohabitation should be interdicted, especially around the second and third months, and more particularly among neurotic women. Psychic disturbances are common causes of abortion. Sudden fear and sometimes great excitement may produce sudden contraction of the uterus and dislodgment of the fetus and placenta.

Malpositions of the uterus, especially retro-flexion, is spoken of by many authors as a common cause. The shaking incident to automobile riding (not spoken of) is undoubtedly a common cause.

The jarring from severe cough in bronchitis and especially in whooping-cough. In all such cases codeine or other opiate should be used at once.

The frequency of criminal abortion is unfortunately very frequent in this country where statistics are often undependable and there is often no way of reaching an accurate estimate. According to Doleris 50 per cent. of all abortion cases coming to the gynecological clinic are criminal.

The means employed and the necessity for secrecy result in a large proportion of women doing the abortion themselves, or in having it done by professional abortionists who are themselves incompetent persons. This results in a large number of deaths from sepsis.

Eclampsia is of course a frequent cause of abortion, resulting in a large mortality to both mother and child. In cases of eclampsia, the best treatment for the mother (narcosis) is frequently fatal to the child. Cesarean section probably offers the best chance for the child and also the mother in many cases, especially in skillful hands.

The diet of the mother in these cases is of greatest importance. It is found in cases of eclampsia that there is a marked retention of chlorides in the blood. It is probable that the albuminous foods also are a big factor.

Placenta Prævia.—Another cause, not frequent but often fatal to both mother and child, is placenta prævia. In this condition as high as 52 per cent. of the infants are born dead. This in skilled hands, and in unskilled hands the percentage of deaths is probably much higher.

Prolapse of the cord. According to Sconzone the mortality of infants in which this occurred was 55 per cent. out of 743 cases.

Premature Births.—Premature births from various causes is comparatively frequent. It is many times impossible, excluding the already defined causes of abortion, to determine why the child should be expelled earlier than normal.

In many cases there appears to be nothing abnormal about the mother, no illness, no excessive exercise and no disease.

The saving of premature infants born after the seventh month of gestation requires special consideration.

According to Cramer, who made an inquiry in many institutions, as high as 81 per cent. of 500 premature infants were still alive, a much greater percentage than could be shown with us.

The maintenance of the body temperature and breast milk are the sheet anchors in these cases.

Clothing of the Prospective Mother.—Clothing of the prospective mother should be loose, warm, and comfortable. All clothing should be suspended from the shoulders. Corsets which constrict the chest and abdomen should be discarded.

During the last months, when the abdomen is pendulous, an abdominal support may be worn if properly fitted.

Prenatal Care.—Proper care of the prospective mother should be exercised from the first months of pregnancy. A physical examination should be made and any abnormality determined and if possible corrected. The urine should be examined regularly at least once a month. The diet and general hygienic surroundings of the family should be carefully scrutinized. The general nutrition should be maintained at as high a point as possible.

Inverted or undeveloped nipples should be recognized early and proper steps taken by means of suction, massage, etc. to properly develop them. Many failures of nursing arise from this cause.

Among the poor, the prenatal clinic, supplemented by the prenatal nurse, is of the greatest value. The follow-up work in many of these cases is imperative. It is only by visiting these people in their homes and demonstrating to them the proper way to live that results can be obtained. It is remarkable how rapidly intelligent women get the idea if properly presented to them. Each woman becomes a missionary in her district and it is not long before the status of the whole community is improved.

Protection of Child During the Puerperal Period.—The lives of many normal infants are sacrificed from faulty technique and from lack of proper protection during and directly after birth. Where there is any deformity or constriction of the pelvis or any malposition of the fetus the delivery should take place in a well appointed hospital. The physician should realize that a complicated obstetric case requires as much skill as the most delicate surgical procedure. The application of obstetrical forceps is responsible for many more serious brain lesions than has been heretofore generally realized. Facial paralyses are common and hemiplegias are not uncommon as a result of pressure.

Forceps should only be applied after nature has been given a fair chance to defend herself, and then only by one skilled in their use.

The possibility of prolapse of the cord and consequent strangulation with resulting asphyxia and inhalation of amnia by the fetus should be borne in mind and every means taken to prevent such a catastrophe.

Injuries resulting from traction on the extremities in the process of delivery frequently occur. Fractures of the bones of the arms and legs are not infrequent as are also injuries to the nerve trunks resulting in some degree of paralysis either temporary or permanent in character.

Many infants succumb during the first week as a result of exposure during delivery. Young infants lose heat rapidly, the body temperature sinks to subnormal, frequently resulting in catarrhal infections of the respiratory tract and even pneumonia. As soon as the cord has been tied, and even before, the baby should be rolled in a warm blanket and removed out of harm's way. It should, however, be watched closely to see that it breathes properly and that the cord does not bleed. It has been demonstrated that after a bath the temperature usually falls below normal.

Asphyxia.—A considerable number of apparently normal infants, especially those who have been subjected to a long difficult birth, do not begin automatically to breathe directly after delivery. These cases are usually cyanosed to some degree although at first the skin and mucous membranes may be very pale, the cyanosis beginning only after the pulsation of the cord has ceased. It is probable that either as a result of pressure or an accumulation of toxic products in the blood, the respiratory centers have been so interfered with that they lack the power to functionate.

If there has been a serious injury to the brain involving the respiratory center the inability to breathe may be permanent and the child will die as soon as artificial respiration has been discontinued. In many cases, however, the condition is temporary and after artificial respiration has been resorted to for a time the breathing goes on automatically. As soon as the infant is born all secretions should be removed from the nose and mouth and the character of the heart action determined.

A dash of cold water on the face and chest will often tend to produce a respiratory effort sufficient to partially inflate the lungs after which the automatic breathing may continue. If, however, the cold water does not at once produce the desired result it should not be persisted in, but the child should be rolled in a warm blanket and artificial respiration begun at once. As long as the heart continues to beat there is always a good chance that the breathing will become normal.

Whatever means of artificial respiration is employed the important point is that air enter the lungs and then be expressed. The number of induced inspirations and expirations should not exceed 18 to 25 to the minute. After a few have been given a pause should be made sufficiently long to see if any effort is made on the part of the baby and, if so, it should be permitted to continue and the artificial respiration stopped. If the cyanosis does not quickly disappear some further assistance with the idea of inducing a proper areation of the blood should be given.

When the cyanosis persists after respiration seems normal it is probable that either there is an improper inflation of the lung (Atelectasis) or that there is a congenital heart lesion (see chapter on heart).

Tying and Care of the Cord.—Improper care of the cord is responsible for many serious conditions in newborn infants.

Hemorrhage from the stump of the cord is a not infrequent cause of death. When the cord is very large it contains much jelly that requires considerable force applied to the ligatures in order to properly constrict the vessels. A careful inspection should be made several times within the first 12 hours to see that there is no bleeding from the cord. It has been our experience in the hospital that not infrequently bleeding occurs from the cord several hours after it has been first tied and where there was no bleeding directly after tying. No reference is made here to Melena Neonatorum or to cases suffering from Hemophilia where the bleeding will continue in spite of any amount of tying. In these cases the cause is constitutional and not local, and other remedies such as transfusion of blood must be resorted to. The care of the cord is of the greatest importance as infections at this point are especially serious.

It is probable that if the cord were left without any dressing at all except to be surrounded by sterile gauze and allowed a free access of air that there then would be fewer infections than where applications in the way of dusting powders are applied, many of which are not sterile. When no application except sterile gauze is applied the cord quickly mummifies, there is no culture media for bacteria, and there is no interference with the development of the epithelium of the skin which rapidly closes over the navel.

Any infection about the navel is particularly serious as pathogenic organisms may be carried directly to the liver through the collapsed vessels, resulting in a general systemic infection.

After the cord has separated, and if there has been no infection, the raw surface at this point of separation becomes covered with epithelium and is lost in the folds of the umbilicus. Not infrequently this small surface does not heal over but instead continues to granulate producing a small pediculated mass the size of a French pea hidden in the folds of the umbilicus. This keeps up a continuous sero-purulent discharge. The proper treatment of this condition is to have an attendant grasp the mass with a blunt forceps and then with a sterile ligature tie off the pedicle. The mass will then mummify. The whole area including the pedicle may be touched with a 5 per cent. solution of iodine to prevent any possible infection, and the discharge will cease at once. For the future it is only necessary to keep the recesses of the umbilicus clean.

Bathing of the Newborn.—There is no necessity that newborn infants should receive a bath during the first few hours. Infants who are not especially vigorous and particularly those who have been subjected to a long hard labor and have had considerable exposure are much better if simply rubbed with warm oil, wrapped in a warm blanket and left from 12 to 24 hours.

Newborn infants should be exposed only for very short periods of time unless the room is at body temperature. The water for the bath should be about 100 degrees and should be preferably rain water and boiled.

If well water, which usually contains considerable lime salts, is used, a little borax (one drachm to the quart) will improve the softness greatly.

During the first week, or until the cord separates, only sponge baths should be given and then only under a blanket unless the room temperature is above 85 or 90 degrees.

Soap should be used sparingly and only the best quality should be used at all. The average cheap soap contains considerable unneutralized alkali and is extremely irritating to the delicate skin of the young infant. In giving the bath little friction should be used as the epithelium is easily rubbed off and a dermatitis results. Where there is a large amount of vernix caseosa it should not be removed at one bathing but only that which can be removed without friction, the baby re-anointed with warm oil and the remainder removed at the following or subsequent baths.

Many infants after the first days suffer from intense redness of the skin often accompanied with tiny pin point pustules. This is usually due to irritating soap or to too much friction, or both.

It is imperative that the skin where soiled with the stool or urine should be cleansed at once and all secretions from the folds of the skin removed, otherwise a dermatitis will soon result. The skin should be dried by sponging with a soft towel and not by rubbing, as undue friction might by removing the delicate epithelium set up a dermatitis.

Following the bath the skin may be dusted with some bland insoluble powder such as stearate of zinc or corn starch.

Toilet powders which contain boracic acid or other soluble drugs are often irritating to the skin as they soon dissolve in the perspiration or urine and add to rather than diminish the irritation. It is not necessary unless the conditions are ideal that young infants should have a general bath daily if the soiled areas are kept clean by sponging, in fact it is a daily experience in hospitals to see newborn infants receiving their daily bath where the temperature of both room and bath is far below what is proper.

I have witnessed young infants during the process of bathing left exposed for a considerable time while the nurse was called away to perform some other duty. If the temperature of such an infant were taken an hour afterward it would be found to be subnormal, and the following day this infant would usually be suffering from sniffles with considerable rise of temperature.

Professor Budin found that in Paris where many of the infants were brought to the clinics poorly clad that their temperatures were frequently subnormal and that the death rate of these infants was enormous, many of them succumbing to pneumonia. The exposure of young infants cannot be too strongly condemned as it is responsible for a large percentage of the mortality.

Care of the Genitals.—The care of the female genitals requires nothing more than simple cleanliness. Great pains should be taken to separate the folds of the labia at least once daily and remove all secretion and excretions by gentle sponging. Soap should not be used as it irritates and smarts the delicate mucous membrane. In cleansing a female infant which has been soiled with the stool the sponging should be carefully done from before backward so as not to introduce fecal matter into the vagina or urethra. It is a well recognized fact that about 90 per cent. of the cases of pyelocystitis occur in female infants, a fact which points strongly to the probability of the infection being an ascending one.

No dusting powders should be used in or about the vagina as they act as a foreign body and produce irritation. Simple cleanliness is the best protection against irritation of the skin and mucous membrane.

Regarding the care of the male genital organs there is great diversity of opinion. In the care of the penis of the male infant, I think it is fair to assume that nature has not made as many blunders as many would have us believe.

All male infants have an adherent foreskin at birth. From several thousands of observations I have found that there is a considerable difference in the length of the foreskin, and the degree of adherence around the meatus, in different individuals. Whatever may be the facts regarding the lack of susceptibility to infection later in life in those who have been circumcised, it is certain that nature never intended that infants should be circumcised at birth. If left alone about one-half of the cases will right themselves within the first year. The foreskin will gradually become dilated and the adhesions will break of themselves. Where dilation does not occur within the first year and where the foreskin is tightly adherent around the meatus, circumcision or stretching may be required. In many of the cases where the foreskin is long and even when it can be pushed back it would be much better and more readily kept clean if a circumcision were performed. In some cases before the adhesions are broken up it will be found that there is considerable irritation produced by an accumulation of smegma behind the glans penis. When this occurs the adhesions should be forcibly broken down with a probe, the secretion removed, and if necessary a circumcision performed.

Forcibly pushing the foreskin back daily in young infants is unnecessary and frequently paves the way for the vicious habit of masturbation.

Care of the Mouth.—Contrary to what has been generally believed and often taught, the mouths of young infants do not need daily cleansing. If directly after birth it is found that the mouth or pharynx contains mucus which threatens to interfere with breathing, the mouth should be gently swabbed out with some sterile cotton, wound on an applicator or over the index finger. The forcible swabbing of the mouths of infants by means of gauze stretched over the finger is a frequent cause of sore mouth (Stomatitis) in infants. Wherever any of the epithelium is rubbed from the mouth or tongue a white exudate results. The secretions of the salivary glands suffice to keep the mouth of the young infant clean.

After the teeth come through, food accumulations on them should be removed by means of a soft brush or by other means.

Care of the Eyes.—Since it is a known fact that 80 per cent. of the cases of blindness result from gonorrheal ophthalmia (Ophthalmia Neonatorum) acquired from the vaginal secretions of the mother during birth, it is of vital importance that the eyes of the newborn receive the necessary care. The eyes should be irrigated almost immediately after birth with a warm boric acid solution and if the mother has any vaginal discharge a 2 per cent. silver nitrate solution freshly made should be dropped into the eyes.

It would be a safe procedure if it were taken for granted that every case were infected and this procedure practiced by every physician or midwife as a routine.

In many states this is now compulsory in all cases, so that it is probable that in the near future this law will be in force in all the states of the union.

In all cases where there is any evidence of inflammation in the infant's eyes, as evidenced by the redness of the conjunctivæ, or discharge, a smear and culture should be taken at once and the character of the infection determined. It would be well in all such cases, without waiting for a report of the culture, to drop a 2 per cent. solution of silver nitrate in each eye. Following the silver nitrate a slight reaction may result, which however is insignificant and rapidly disappears.

If after the first cleansing the eyes appear normal and no discharge appears it is only necessary to keep the eyelashes and corners free of secretion. This may be done preferably with a normal salt solution. Daily washing with solutions such as saturated boric acid is unnecessary and even harmful. If the eyes are normal, the secretions of the lachrymal glands suffice to keep the eyes under normal conditions clean.

Clothing of Infants and Children.—The proper clothing of infants is dependent upon several important facts. It must be remembered that the primary object of clothes is to maintain the body temperature at a constant degree. An infant has a greater body surface in proportion to its weight than older children and adults, which offers a greater opportunity for loss of heat by radiation and evaporation. It is an undisputed fact that owing to the lack of development of the heat regulating centers a young infant is not able to maintain a constant body temperature under varying conditions of heat and cold. A natural conclusion would be therefore that under a given temperature infants would require more clothes than older children. The amount as well as the quality of the clothing will depend somewhat on the character of the climate, the temperature and humidity.

The infant should be so protected by clothing that he is never exposed to excessive degrees of heat or cold. Sudden changes in temperature should be met by varying the amount and quality of the clothing. Woolen should be theoretically worn in cold weather while in hot humid weather when greater evaporation is required the clothing should consist of cotton, muslin or other material which conducts heat much more rapidly than woolen. In extremely hot weather the only object of dress is to cover nakedness in compliance to convention and to protect the sensitive skin from the sun, dust, flies, etc.

In summer most children are over clothed and it will be found that many of the illnesses from which children suffer in hot weather are due to a combination of over-feeding and excessive clothing.

The clothing about the chest and abdomen should be sufficiently loose so as not to impede the functions of either the digestive or respiratory organs. A tight binder about the abdomen is a common cause of the regurgitation of food in young infants.

Undergarments.—It is important that the undergarments should be fastened with tape instead of pins or buttons. In pinning the diapers it is not an uncommon thing that portions of the skin and even the scrotum are included.

When a baby shrieks as if in pain it is always advisable to see if a pin may not be the exciting cause.

In pinning the diaper to the shirt it is important not to pin it so that it will produce undue tension on the shoulders thereby causing deformity. As soon as children are able to walk all clothing should be suspended from the shoulders. The best manner to do this is by means of a properly constructed waist to which the clothing is fastened. A waist known as the Golthwait with broad shoulder straps extending well up to the base of the neck is an ideal form and may be made at little expense. The ordinary variety purchased in the shops has narrow shoulder straps which usually fall out on the points of the shoulders thereby tending to drag them downward and forward.

A very light woolen shirt of a mixture of cotton and wool even in the hot summer months in the north, excepting extreme weather, will be found to protect children from the sudden changes of temperature and from becoming chilled after vigorous play.

Abdominal Band.—A newborn baby should wear an abdominal band until the navel is healed. It may then be discarded. This binder should be six inches wide and should be made of flannel. It should be worn snugly but not too tightly around the abdomen. A tight abdominal binder is often the cause of regurgitation of food. There is no ground for believing that the abdominal binder protects the infant from intestinal disorders. It is much more frequently the cause of intestinal disorders, particularly in hot weather.

Diapers.—The diapers should consist of soft non irritating material, preferably cotton, which readily absorbs moisture. A large number of diapers, two or three dozen, are necessary in order to be able to make frequent changes. Diapers should be changed as soon as soiled. Soiled diapers always produce discomfort and not infrequently irritation of the skin. It is not improbable that soiled diapers may produce infections of the genito-urinary tract, especially in girls. It is a recognized fact that fully 90 per cent. of the cases of pyelocystitis occur in female children. The soiled diapers should not be used the second time without first being washed, boiled and dried. A common practice of allowing diapers which have been soiled by urine to dry and then use them again without boiling should be condemned. The diapers should be applied loosely to allow free movements of the legs and should be secured by tape if possible, instead of pins.

When children are out of doors in cold weather the feet, legs and hands as well as the body must be kept warm. Children will not play out of doors in cold weather unless they are comfortably dressed. Over-shoes and woolen over-stockings should be provided which can be removed when indoors. The greatest care must be exercised when young infants are out of doors in cold weather. It is not uncommon to see infants whose faces have been frosted from exposure even for a short time in zero temperature. Young children should not be taken out in zero weather and under all conditions young children when out of doors in cold weather must have special wrappings of wool in order to maintain body temperature.

Young infants should wear woolen stockings in cold weather and cotton in moderate weather which may be attached loosely to the diaper so that the feet may have ample freedom of movement. It is much more logical to allow children to wear sufficient clothes so that they do not have to be pinned under blankets thereby greatly limiting their bodily movements.

Shoes.—Shoes for young infants, if worn at all, should be of soft leather allowing perfect freedom of all muscles. Shoes for older children should be without heels up to the age of 8 to 10 years. High heels should never be worn. Sandals with broad toes are excellent for summer, protecting the feet from injury, and are the next best thing to going barefoot.

List of Clothing for Infants.—The following list of clothing will be appropriate for a young infant. Fewer articles may be sufficient but more frequent laundering would be necessary.

Two to five dozen diapers, 20 by 24 inches. These should be of soft cotton material.

Four to six shirts; soft woolen, or cotton and wool, or silk and wool. For hot weather the shirts should be of the thinnest wool, and if the weather is extreme they may be of cotton.

Six bands, flannel or knitted, six to eight inches wide. During the hot weather they may be discarded if a thin woolen skirt is worn.

Six skirts, flannel. During hot weather cotton or muslin should be worn.

Six night gowns, of outing-flannel or cotton (for summer). They should be long enough to pucker at the bottom with draw strings over the feet and large enough not to interfere with the movements of the legs.

One dozen dressing slips, of simple wash material of various weights. Expensive linens with embroidery are only for the rich. There is no good reason for the length extending beyond the feet.

Three blankets, or comforts, of varying degrees of warmth for different weather.

Two knitted sacks.

Six or eight quilted pads for the basket or bed.

One cloak.

Two caps; one warm, one cool.

Two veils, without color.

Two rubber blankets, one yard square.

One hair pillow, 10 by 12 inches, one to two inches thick.

Six pillow covers.

Six sheets.

The Nursery and Its Equipment.—The nursery should be a good sized room and should be provided with at least two windows which face in opposite directions. It should be so located that it will have the direct sunlight for at least a part of each day. The south and east facing room is generally to be preferred, since during the winter months the sun shines in these windows a great part of the day and during the hot summer months the hot afternoon sun is to some extent avoided. During the summer, awnings, especially on the south and west windows, are almost a necessity.

All windows should be provided with screens to exclude flies and mosquitoes as well as other insects. Hangings and pictures should as far as possible be excluded and only the simplest wash curtains be permitted. The floors should be of hard wood or tile and may be covered with small rugs which may be washed. The floors should be mopped regularly once or twice weekly. A vacuum cleaner or carpet sweeper should be used in preference to a broom for removing dust from the floors, since the latter simply suffices to stir up the dust and change its location.

The walls of the nursery should preferably be of plaster which may be painted some restful color and which may be wiped with a damp cloth without injury. In place of pictures with frames a fresco of appropriate figures may be substituted.

Ventilation.—The air in the nursery must be kept constantly fresh; it is therefore necessary to have a continuous change of air from without. During the summer months when the weather is warm and the windows may be kept wide open this is a simple problem, but in winter, particularly during extreme weather, it is often a difficult problem to have proper ventilation and at the same time maintain the temperature of the room. Opening a window slightly at top and bottom creates a rotary motion of the air thereby promoting good ventilation. Most of the patent ventilators which are on the market have a limited value and many of them are entirely useless. It is not sufficient, as is too frequently supposed by the laity, to open the windows once daily so that the room may be aired. It is absolutely necessary that some change of air however slight should be constantly in force.

As few persons as possible should be in the nursery at any one time and when the baby is asleep it should be alone. The mother, or nurse, should sleep in the adjoining room with the door open so that any noise made by the baby, such as coughing, vomiting or difficult breathing, may readily be heard. A bath-room and toilet, adjoining the nursery, for the exclusive use of the child and nurse is not a necessity at all times but a great convenience and during any contagious affection an absolute necessity.

Temperature.—The temperature of the nursery for the first few months should be very uniform, about 68 to 70 degrees during the day and at night and during the sleeping hours it may be slightly lower. During the bath, the temperature should be considerably higher, say 75 to 80 degrees, since infants lose heat very rapidly when the surrounding temperature is below body heat. Young infants should never be put to sleep in a zero or sub-zero temperature. It is not difficult to imagine that air at such temperatures inspired at the rate of 30 per minute must be extremely irritating to the delicate mucous membranes of the respiratory tract of the young infant. The essential thing is that the air be fresh and it is not necessary that the air be cold in order to be fresh. It is not an uncommon mistake to find a whole family consisting of father, mother and several children sleeping on a porch with the windows closed. They are usually laboring under the delusion that they are obeying ultra-modern health rules because the air is cold.

During the hot weather, especially when the weather is humid, and especially when there is no breeze, an electric fan will be found to be of great benefit since it is in the movement of the air that evaporation is increased. It should be remembered, however, that young infants are very susceptible to rapid changes in temperature so that the current from the fan should not be too directly turned upon them.

Heating.—The means of heating the nursery is of great importance. The most common means in vogue today are the stove, the central heating plant which may be hot air, hot water or steam. Any central system may be regulated by means of a thermostat so that the fire may be controlled, giving a uniform temperature throughout the house. A point of great importance is that frequently during the cool days of spring and fall and even occasionally during the summer months a central heating plant is rarely in commission. It is therefore usually necessary to have some means of heating the nursery and adjoining rooms. This can best be done by means of a wood stove or better still a fire-place, which at the same time acts as an excellent means of ventilation. Another important advantage of the stove is that a kettle containing water may be kept boiling so that the air has sufficient humidity. Regarding the humidity of the air when the nursery is heated by a central plant, with hot water it will be necessary to adjust some form of humidifier to the radiators so that sufficient amount of water may be evaporated. With steam heat the vent may be left sufficiently open to secure the proper amount of moisture and with the hot air the modern furnace is provided with a large receptacle attached to the furnace itself which vaporizes a sufficient amount of water while it is in operation. See chapter on ventilation and humidity.

Lighting.—The lighting of the nursery is a matter of great importance. Whatever form of light is provided should result in as little contamination of the air as possible in the way of consuming oxygen, producing irritating gases, and in the production of bad odors. The form of light which meets all of these requirements best is a properly modified electric light.

Lights should be so placed and modified by globes and shades as to produce a soft non-irritating light. Bright light should not be allowed to shine directly into a child's eyes, and during sleeping hours all light should be extinguished. A gas jet should never be allowed in a sleeping room. It is practically impossible to make the joints sufficiently tight so that some gas does not constantly escape, there by rendering the air poisonous even to the point of great danger. Any open flame such as a gas jet should never be allowed to burn in the nursery unless there is plenty of air being admitted from without. The author has seen a child asphyxiated as a result of a gas flame burning in a small room with the windows and doors tightly closed. If some light must burn at night in the nursery and an electric light is not available, a small wax candle will use up a minimum of oxygen.

Beds.—The best bed for the newborn baby is an ordinary clothes basket which has been painted with white enamel. Draping, if any, should be of simple white material. The basket may also be lined with some simple wash material which can readily be removed. A mattress stuffed with fine excelsior or hair should be provided. Over this should be a water-proof sheet and this in turn covered with a cotton pad to absorb the urine. Feather pillows should not be used in place of a mattress; they are insanitary, especially in hot weather. The basket has many advantages over a bed for young infants: it is cheap, readily moved about, and the high sides if covered with some impervious material offer a protection from the cold.

At the age of six or eight months the baby may be transferred to a crib instead of a basket. The crib should be of iron or wood painted with white enamel. The sides should be capable of being lowered or swung down from the lower border on hinges. A very important form of bed for hospital use or even for the nursery is one in which the springs and mattress may be raised within the frame to the desired height. The constant stooping over a low bed is extremely fatiguing to the mother or the attendant. The mattress for the crib may be of the same material as that for the basket and should be covered with a water-proof sheet and a cotton pad. In addition to the bed or basket a nursery should contain all the necessary articles for the use of the toilet.

These should be arranged in a manner to save the time and energy of the mother or nurse. The following articles may well be included in every well regulated nursery:

A folding or ordinary kitchen table upon which the baby may be dressed, undressed and changed. The top may be covered with oil cloth which should be washed off daily with a damp cloth.

A bed screen, to be covered with simple wash material. A dressing table with a glass or porcelain top and a shelf below, also of glass or porcelain. A railing one inch high should surround the top and shelf, to prevent articles from falling off. The legs of the table should be provided with large casters so that it may be readily moved about the room. It should be low enough to be within reach of the nurse without her getting up. The table should be equipped with the following articles:

1. One bath thermometer.
2. Clinical thermometer.
3. Talcum powder (unscented).
4. Stearate of zinc powder.
5. Tube of yellow vaseline (the jar vaseline is insanitary).
6. Boric acid crystals.
7. Box of zinc oxide ointment (preferably a tube).
8. Bottle of alcohol.
9. Bottle of sweet oil or olive oil.
10. Castile soap (best quality).
11. Blunt bandage scissors.
12. Safety pins (assorted).
13. Needles and white thread.
14. Soft wash cloths and towels.
15. Soft baby hair brush.
16. Absorbent cotton (sterile).
17. Tooth-picks, to wrap cotton about as swabs (to be discarded and burned after using).

A receptacle with a tight fitting lid, preferably of enamel, should be provided for soiled diapers. This should stand in the bath room but may remain in the infant's room if necessary without producing bad odor if the lid is kept closed. It is always important in cases of children with any abnormal condition that the stools should be preserved for inspection by the physician. The total number for the 24 hours should be kept.

A pair of accurately weighing scales is an absolute necessity for the nursery. The ordinary variety with a dial depending upon the recoil of a spring is usually inaccurate. The best variety is the beam-scale and may combine both a scoop for small infants and a platform for older children, weighing as high as one hundred and fifty pounds.

Time to be Spent Out of Doors.—During the months when the weather is warm even very young infants should spend as much time as possible out of doors. This does not mean that they should be pushed about in a perambulator or taken riding in an automobile. Such procedures expose the young infant to dust to which he is very sensitive resulting usually in catarrhal inflammation of the air passages, in restlessness and inability to sleep. Children may usually secure sufficient sun and air on their own porches or in their own yards. If the windows of the nursery can be opened widely, as with casement windows, for example, children may be practically out of doors while remaining in their own rooms.

During the extremely hot weather, rooms on the shady side of the house will frequently be cooler than out of doors. Certain beds inclosed by fine screens and provided with rubber tired wheels may now be purchased which may be pushed out on the porch or on the lawn. The position may be readily changed according to the sun. In crowded parts of the city where there are no lawns, children during the extreme weather should be taken into the open spaces in the parks as much as possible. Some cities, New York and Boston, for example, are providing floating play grounds and hospitals for both well and sick children. They may be moved where they can secure a maximum of fresh air.

In the northern climates during the winter months it is a difficult thing to decide just how long and how often, if at all, young infants should spend out of doors. Infants who are born at the beginning of winter, even if they are vigorous, should be taken out of doors during the first two or three months only when the temperature is above 45 or 50°F., and even then not when the wind is blowing strongly and the air charged with dust. It is more practical during mild days that the baby be dressed as if for going out and the windows or doors opened widely for a brief period. During the winter months, during the sunny part of the day the baby should be placed so that it can receive the direct rays of the sun, a shade being arranged so as to protect its eyes from the direct rays. After five or six months the baby may be put to sleep out of doors when the temperature is not below freezing. The important point is that infants be gradually accustomed to sleep in progressively low temperatures and that the temperature is not suddenly changed from a high to a low degree.

It is of vital importance to remember that young infants do not tolerate well either extremes of heat or cold, and also that cold air is not necessarily fresh, and that is not necessary that air be cold in order that it be fresh.

Sleep.—During the first year infants should sleep from two-thirds to three-quarters of the time. During the second year they should sleep at least 16 hours out of the 24 and even up to the sixth year they should sleep 12 hours during the night with a two-hour nap during the day. It is during the period of sleep that the process of repair is probably most active. It must be remembered that the brain of the child develops more during the first three years than it does during the remainder of its life, so that the most favorable conditions should be maintained for the development of the extremely unstable nerve centers.

The respiration during sleep in young infants should be practically noiseless. The respiration, as in adults, is deeper and slower than during the waking hours. In young infants the rhythm is sometimes very irregular and is largely diaphragmatic. The noiseless character of the breathing in young infants and the fact that it is largely diaphragmatic is frequently a source of anxiety to the young mother. If she is directed, however, to observe the abdomen instead of the chest she will at once be able to observe that the breathing is going on normally.

Nose and Mouth Breathing.—Infants should breathe through the nose and with the mouth closed. When children sleep with the mouth open it is a fair indication that the post-pharyngeal tonsil is larger than normal and acts as a mechanical obstruction to breathing through the nose. This inability to breathe through the nose is a frequent cause of inability to nurse since a child cannot suckle unless it can breathe through its nose. An infant should never sleep in the same bed with the mother or nurse. It is not an uncommon occurrence that young infants are accidentally smothered by the mother while she is asleep. Infants who sleep with the mother are liable to nurse at irregular and frequent intervals throughout the night to the detriment of both.

Rocking the Baby.—The old habit of rocking or walking the baby to sleep is a pernicious one and has nothing to commend it. A baby who is rocked or carried will usually promptly wake again as soon as the movement ceases. After a brief period a baby becomes so spoiled that it will cry incessantly so that it is almost impossible to tell whether the baby is sick or not. A baby should be fed and then put down, its position being changed at intervals to promote emptying of the stomach. It has been demonstrated that the stomach empties itself in some positions better than others.

The best position to promote the emptying of the stomach is one in which the head and thorax are on a slightly higher plane than the abdomen.

Restlessness During Sleep.—The common causes of restless sleep are over-feeding, over-clothing, over-heated and badly ventilated rooms, soiled diapers, inability to breathe properly through the nose, too tight binders and safety pins.

Position During Sleep.—During the first two or three years no pillow should be used. A gradual incline of two or three inches may be permitted, the head of the mattress being to that extent higher than the foot. After feedings, particularly in very young infants who are prone to regurgitate their food, raising the upper part of the body will be found to be of value. The position of the child should be changed at intervals as actual deformity results from constantly occupying the same position.

Sleep for Older Children.—After the third year many children sleep too much during the day with the result that they are restless during part of the night.

Children who sleep two or three hours after the mid-day meal miss the best part of the day when they should be out of doors. It is important that children receive a great deal of exercise in the open air, as it is by this means that their general musculature is developed, their appetites are keen and the assimilation of the food immensely improved. Children who are physically tired will eat better, digest better, develop better and sleep better than those who are pushed about in a perambulator or taken about the country in a limousine.

The Mid-day Nap for Older Children.—The habit of taking a nap in the middle of the day should be enforced as long as possible. Children who are active throughout the day either at school or at play should entirely relax for at least an hour during the middle of the day, even if they do not sleep. If over-worked mothers could be persuaded to adopt a rule of resting in the recumbent position for an hour or so in the afternoon the responsibilities of the family cares would weigh much less heavily upon them.

CHAPTER X

CLIMATOTHERAPY

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GENERAL PRINCIPLES

We can best appreciate the value of climatotherapy when we recall that most of our physical remedies apply but one agent at a time. Climatic treatment comprises not only the application of heat and cold, but also the utilization of atmospheric pressure, sunlight, a species of massage by the winds, and the moisture of the air We may, therefore, recognize that such treatment will often be superior to any one physical agent, but we also see that careful study and discrimination are requisite, as we apply any particular climate to the individual patient.

Climatic treatment may be employed to act either as a stimulant or a sedative. Each of these purposes calls for different combinations of the various climatic factors, namely, temperature, sunshine, humidity, air pressure, and air in motion. To utilize advantageously any one combination of these, such as constitutes a climate, we must begin by considering separately the physiological action of each climatic element.

Temperature.—The nude body of the normal child, when at rest, in an atmosphere containing about 60 per cent. of moisture, maintains its warmth of 99 degrees most easily at a temperature which ranges from 95 degrees in early infancy to about 85 degrees at puberty. This may be called the indifferent temperature, which is reduced about 10 degrees by ordinary summer clothing, and 15 to 20 degrees by heavy winter garments. At still lower temperatures additional body heat must be generated; this is accomplished by increased oxidation of the tissues, but most readily achieved by muscular exertion. Moderate exercise, such as walking, lowers the indifferent temperature about 10 degrees more; this measure is of course not available for infants or very young children. Thus living and school rooms for older children require artificial heat whenever their temperature falls below 65 degrees, whereas the young infant's room should have a temperature of not less than 75 degrees. Out of doors older children, when indulging in active play, will not require extra wraps at shade temperatures above 55 or 60 degrees; at rest even when the temperature is 10 degrees higher, they need overcoats or like garments. Exposure to the direct rays of the sun introduces a factor so variable, as not to be reducible to figures; it must suffice to state that sunshine affords a leeway of an indefinite but considerable number of degrees, so that a sunny and sheltered spot may feel comfortably warm when the shade temperature is below the freezing-point.

The sedative indication is therefore fulfilled in a climate affording a daytime temperature between 70 and 80 degrees, corresponding to a much lower average, for the night temperatures concern us relatively little, as then the patient is indoors. Lower daytime temperatures are restful only if exercise can be indulged in; therefore they are not appropriate for early childhood or extreme invalidism. During the day when the temperature is below 60 degrees, the hardening influence predominates; when a sedative action is desired, so cool a climate is contraindicated. We therefore see that the theory of the indifferent temperature renders possible a very delicate adjustment of temperature, rest, and exercise; we also see how precise but also how difficult climatic treatment becomes when we employ it as a method of hardening, and how simple it is when rest is the sole desideratum. The key to the problem lies in the adjustment to the patient of temperatures below the indifferent point; we shall return to this subject when we discuss the valuable but often abused procedure commonly called hardening.

When the air temperature rises above the indifferent point, even though the body is at rest and lightly clad, more heat is produced than the body requires. In the first instance, the disposal of its surplus warmth is effected by radiation, which is limited at best and greatly interfered with even by light clothing. The final resort of the organism, to counteract a high temperature, is the production and evaporation of sweat, which is very effective under favorable conditions. The mere production of sweat, however, calls for additional work on the part of the vasomotor apparatus with a consequent accelerated action of the heart; heat is therefore a stimulant, not a sedative, a point often lost sight of by climatotherapists who confuse moderate warmth with tropical heat. We have set the border line at 85 to 95 degrees, according to the child's age; but these figures are, as we have seen, much too high when physical exercise must be allowed for.

In considering the effects of variations of temperature, it is necessary to observe that these are most acutely felt in the neighborhood of the indifferent temperature, particularly therefore in the late spring or early autumn. Temperatures below zero, remote from the indifferent point, all feel much alike, so that − 30 degrees in the Adirondacks seems very much the same as zero in New Jersey.

Humidity.—In discussing the importance of perspiration at high temperatures, we must not overlook the role played by atmospheric humidity. Dry air greatly favors the evaporation of sweat, so that the temperature of the body, even in hot weather, is easily kept down to the normal. When the humidity of the air approaches the point of saturation, perspiration is checked; in combination with a high temperature this leads to an accumulation of body heat, thermic fever or heat-stroke, miscalled sun-stroke. In this respect the danger line is somewhat higher for children than for adults, approximately at 75 degrees for saturated air and 90 degrees with 50 per cent. of humidity. These conditions are frequent only in very warm summer climates, thereby accounting for the relative rarity of heat-stroke in childhood.

The sensible temperature, that is the temperature as felt by the human body, is the mathematical function of the thermometric temperature and the relative humidity. Temperatures above 60 degrees should never be considered physiologically by themselves, but always in connection with the percentage of atmospheric moisture; at lower temperatures, where perspiration is insignificant, the humidity is practically imperceptible and may be disregarded.

Sunshine and Cloudiness.—Excessive cloudiness is an objectionable climatic factor, acting as a psychical depressant, and cutting off much of the beneficial effect of sunlight. Sunshine is of inestimable value in the winter, elevating the temperature during the day, acting as an efficient germicide, and giving the individual exposed to it the benefit of direct heat and light radiation. On the other hand, certain summer climates furnish so great an excess of sunshine as to overstimulate the patient exposed to it. During the warm season, therefore, a certain amount of cloudiness is undoubtedly sedative and beneficial.

The germicidal and stimulating effects of exposure to direct sunlight are now being employed extensively in the procedure called heliotherapy. In this connection it is well to pay attention to two points: First, the danger of producing a severe dermatitis by prolonged exposure, before the skin has become gradually inured to this treatment; secondly, the circumstance that the solar rays are much more powerful at high elevations than at the sea-level.

Rain and Snow.—An ample rainfall, if not too frequent, and well distributed through the warmer months, is always desirable, as it purifies the air and checks the formation of dust. An excess of rainy days is objectionable, interfering with outdoor life and acting as a psychical depressant.

In winter, a permanent snow-sheet is advantageous, facilitating outdoor life and acting as a complete preventive of dust. It has the one drawback of melting very suddenly in spring, and rendering at least a part of that season disagreeable on account of slush and mud. In climates where the winter temperature averages near the freezing-point, the stated unpleasant conditions exist during a large part of the cold season; more severe or decidedly mild winter climates are in every way preferable.

Winds.—Moderate winds are a great desideratum, especially in summer; high winds and frequent storms are a harmful feature in many winter climates; frequent calms are unobjectionable in winter, but may greatly impair an otherwise suitable summer resort. Great plains and coasts are especially subject to strong winds; in mountain valleys the winds are gentle, sometimes with an excess of calms and consequent night mists.

Altitude.—The variation in the atmospheric pressure according to altitude is of very great importance; at an elevation of 5,000 feet we are deprived of one-sixth of our air supply, and at 10,000 feet of an additional sixth. To compensate for this deprivation of oxygen, a gradual increase of the red blood cells takes place, amounting to nearly 2,000,000 per cubic millimeter at 5,000 feet, and over 3,000,000 at 10,000 feet in the course of three or four weeks. At the same time the actual, though not the relative, amount of hemoglobin also increases, but somewhat more slowly. While this addition to the blood is taking place, the visitor suffers from a relative anemia, severe at first, then gradually passing off, constituting what is known as mountain sickness. Some persons become affected at 5,000 feet, others only at much higher levels, but nearly everybody at 15,000 feet, where only about one-half of the normal air supply is available. It is evident that previously anemic persons suffer most by removal to high altitudes.

As the atmosphere absorbs a relatively large proportion of the ultraviolet solar rays, these will be especially powerful at high elevations; they are in all probability the cause of frequent sunburn among travelers in the mountains, and seem to be one of the curative factors in the treatment of tuberculosis at high altitudes.

In the valley bottoms of mountainous regions there is a tendency to very intense winter cold and summer heat, and more temperate conditions on peaks and especially on slopes. The humidity and precipitation increase as we ascend, at least part of the way, but night fogs are frequent in the valleys. On high plateaus we find relative dryness, high winds, and a great daily and seasonal range of temperature.

The Seashore.—At the seashore and on islands the summer is usually cooler and moister than inland, because of the sea-breeze; and on account of the warming influence of the water the winter months have a somewhat higher temperature, lower humidity and more sunshine. The precipitation is sometimes increased, sometimes diminished. The seasons, compared to inland situations, are retarded, and the autumn is very much warmer than the spring. The annual average temperature is raised by marine influence northward, whereas southern seaside localities are relatively cool; summer and winter tend to approximate to each other, so that some places show a very small annual range. Seashore points are apt to be windy, northward chiefly in winter, southward in summer, in middle latitudes throughout the year.

Sea-air is relatively free from bacteria, and its purity is undoubtedly of value, especially in southern regions, but the value of the salt spray is problematical. Large bodies of fresh water influence climate similarly to the sea, but naturally to a less degree.

Classification of Climates.—For therapeutic purposes, climates may be classified as follows: First, according to temperature; secondly, according to relative humidity; and thirdly, according to altitude.

The temperature classification includes the following six or seven types:

1. Hot climates. Every month averages over 68 degrees.
2. Warm climates. Every month averages over 50 degrees, the summer over 68 degrees.
3. Truly temperate climates. All months average between 50 and 68 degrees.
4. So-called temperate climates (extreme climates). Some months average below 50 degrees, some above 68 degrees. May be divided into: (*a*) warm temperate and (*b*) cool temperate, according to the winter averages above or below 32 degrees.
5. Cool climates. All months average below 68 degrees, the winter below 50 degrees.
6. Cold climates. All months average below 50 degrees.

The humidity classification includes four types:

1. Desert climates. Humidity under 40 per cent.
2. Dry climates. Humidity averages between 40 and 60 per cent.
3. Moderately moist climates. Humidity averages between 60 and 80 per cent.
4. Very moist climates. Humidity averages over 80 per cent.

As regards humidity, the classification of some localities varies with the seasons.

The third classification, according to altitude, is as follows:

1. Low levels, below 1,000 feet.
2. Moderate elevations, between 1,000 and 3,000 feet.
3. High altitudes, above 3,000 feet.

The summary of these three classifications theoretically affords 72 to 84 different climates; even though some combinations do not occur, still the variety remains confusingly large. We can simplify matters by noting only such climatic types as have a definite therapeutic value. This is best accomplished by a few remarks on climatotherapy in general.

General Application.—Residents of hot and warm regions may avail themselves of a measure of hardening by temporary removal to a cooler climate. A warmer climate involves little change for them, save to increase the enervation already induced by their home conditions.

Residents of temperate regions may avail themselves either of sedative treatment in a warmer climate, or of bracing conditions in a cooler one; they thus enjoy more extensive opportunities. In the truly temperate climates, with a small annual range, the very evenness may cause some enervation. Therefore, a visit to a cold winter climate is likely to do good. Removal to a cooler region is also desirable in the summer months of the extreme so-called temperate climates; the inhabitants of such localities often have two bad seasons to contend with: namely, a hot and enervating summer, and a winter that keeps the less robust individual indoors much of the time; here the field of climatotherapy becomes very extensive indeed.

Residents of cool climates are not likely to require any change except removal to a mild winter resort, which may be selected so as to have either a sedative or a moderately hardening effect. Residents of cold climates are largely debarred from the benefits of climatotherapy. To them any change implies increased warmth, which involves the dangers of at least relative enervation, rendering perilous a return to their inclement homes. The inhabitants of cold countries must, therefore, seek health within their own climatic range.

The benefits to be derived from increased altitude are not limited to the residents of any temperature zone, and the same is true of removal to a drier or moister climate.

The general rules of climatotherapy require some modification when applied to infants and young children. Young subjects are relatively sensitive to cold and sudden changes of temperature. The modifying element of exercise is unavailable during the first 18 months, and of proportionately small account for some time thereafter. At temperatures above the indifferent point, which is relatively high in early life, children of all ages do badly; the mortality of white children is very high in the tropical lowlands, and the summer months of merely warm climates also cause marked enervation. As to the recommendation of high altitudes for the very young, there is some diversity of opinion; the coldest high mountain climates are unsuited to the earliest years of life, but well adapted to older children, while moderate elevations are generally beneficial to all ages.

HEALTH RESORTS

In the following pages we give a detailed climatic description of North American health resorts, supplemented by mention of some of the foreign localities most popular with medical climatologists.

Newfoundland, New Brunswick and Nova Scotia.—These regions are just beginning to come into vogue in the climatotherapy of childhood; the last two quite fulfill the ideal of such persons as desire a really cool summer at the seaside; with not too much wind and dampness. August is the warmest and best month; September is relatively dry, whereas fogs and rainy spells are not uncommon in June and July. The spring months are very disagreeable in this region, owing to frequent cold and damp northeast winds; the late autumn is wet and stormy. Unfortunately, most of the accommodations are primitive throughout the Maritime Provinces, the fare, in particular, being usually inferior.

The Maine Coast.—This section resembles the preceding, but is sunnier and colder in winter. Toward the southwest, the summers are much warmer, so that Portland has some very hot days, such as are almost unknown at Eastport, and uncommon at Bar Harbor. The variations in the weather, according to the seasons, are similar to those of Nova Scotia, but the early summer is drier and warmer, and the cold season somewhat less stormy. Accommodations are in general better than in the Maritime Provinces. Sometimes they are indeed first class, a point of no little importance in the selection of a health resort. As in most of New England, the worst month of the year is April.

The Mountains of Northern New England.—Here the variety of resorts is very great, and the visitor may select anything from the palatial and fashionable hostelry to the primitive cabin in the wilderness of northernmost Maine. Some sections are partially cultivated; others consist chiefly of bare or wooded mountain side. Others again present a tangle of forest, lakes, and trout streams. The higher resorts, at elevations above 1,200 to 1,400 feet, form the favorite refuge for victims of hay fever. Black flies and mosquitoes are troublesome in June and early July in the heavily forested sections, less so in the open country; the best season is later, until mid-September, after which date heavy night frosts with occasional snow flurries are common. The winter is too cold for infants and young children, since at this season there is a large proportion of below zero weather and an excess of heavy snowfalls. The early spring, which usually does not begin before April, is the worst season of all, on account of the sudden melting of several feet of snow.

Among the resorts in this section may be mentioned the lake region of northern Maine, which is still a thorough wilderness, the semi-cultivated but otherwise similar interior of southern Maine, the White Mountains and their foothills in New Hampshire, and the Green Mountains in Vermont. In all these sections accommodations of every class abound.

The Coast from New Hampshire to Long Island.—Here we gradually leave the cool summers of the northeast coast. The temperature, however, remains, on the whole, fairly low as far as Boston, south of which we begin to note a tendency to sultriness, which steadily increases as we approach New York City. In this district the situation with respect to the sea-breeze becomes of prime importance; localities facing east and south are much cooler than those facing west and north. Thus, the south shore of Massachusetts Bay has a hotter summer than the Cape Cod peninsula and the stations on Buzzard's and Narragansett Bays; similarly, the ocean side of Long Island is preferable to the Sound side, which is also inferior to the Connecticut shore. On the outlying islands of Block Island, Nantucket and Martha's Vineyard, high temperatures are unknown, but the nights are no longer very cool, so that the climate is somewhat enervating to older children. Mild malaria exists in the marshy districts of this region, which, aside from the annoyance of mosquitoes, makes it advisable to avoid them.

As we go south, the winter becomes steadily milder. In ordinary seasons, the coast from Nantucket to New York, where marine influence is most manifest, usually experiences an open winter. Here zero weather is rare, but the outer islands, because of high winds and severe storms, are rendered quite unsuitable to a winter sojourn. Westward, these disagreeable conditions are less in evidence; the percentage of winter sunshine is high, and the climate in general approximates that of the New Jersey coast.

The objectionable northeast winds of spring become less trying, as we go south and west from Boston, though on Long Island the transitional month of March, with its uncertain mixture of winter and spring, is the worst of the year. September and October are very fine in this section, with some hot days in the former month; southward November also affords good weather in ordinary years, as the winter does not usually set in before December.

This region abounds in accommodations of every grade, suitable to every purse. The outer suburbs of the great cities are particularly to be recommended as health resorts or permanent abodes for children.

The Adirondack Mountains.—The mountainous parts of northern New York closely resemble those of northern New England, not so much the semi-cultivated country of Vermont and New Hampshire, as the lake-strewn wilderness of northern Maine. The climate of the two regions is identical. Saranac Lake is practically a vast sanatorium for the tuberculous; and thus keeps most of these patients away from other resorts that are quite as attractive. On the average, the accommodations are somewhat inferior to those of northern New England; the fare is not always as good as it should be so that some discrimination is necessary.

The foot hills of the Adirondacks are not as frequented as those of the Green and White Mountains, and have a rather warm summer, which becomes unpleasantly hot in such low-lying situations as Lakes George and Champlain, and Saratoga Springs.

All the remarks as to the respective merits of the seasons that were made concerning the mountains of New England apply equally to the Adirondacks. Black flies and mosquitoes are very troublesome until the middle of July.

The St. Lawrence Valley.—This region somewhat resembles the last, except that the winter is still colder. Along the river itself, from the Thousand Islands to Quebec, the summer is rather warm. Below Quebec it rapidly grows colder, and beyond the mouth of the Saguenay River it is, even in August, too raw for young children. Good accommodations are obtainable only at a few points outside the larger cities; the low-priced resorts are apt to be decidedly primitive.

The Lower Hudson and Connecticut Valleys.—Along these rivers there is a large number of resorts, all very warm in midsummer, and not sufficiently severe in winter to ensure a permanent snow-covering. As we ascend the hills on either side, however, both these objections disappear; the Berkshire and Litchfield Hills, as well as the Catskill and Shawangunk Mountains, afford hundreds of attractive sites with a pleasant climate. The Hudson and Ramapo highlands are picturesque, but not sufficiently elevated to avoid the summer heat. As these regions form the outer fringe of the metropolitan zone, accommodations are increasing in number and improving in quality at a very rapid rate. It is best to avoid the favorite stopping-places of motorists, as they cater chiefly to transients, and are therefore unsuited to children requiring prolonged climatic treatment.

New Jersey.—Northern New Jersey resembles the last-named section, but rarely exceeds 1,000 feet in elevation. It is, therefore, rather hot in midsummer, and neither really cold nor mild in winter. The southern part of the state is low, flat, hot in summer and somewhat malarious inland, tempered by frequent sea-breezes on the coast. In ordinary winters the climate is moderately mild, with very rare zero weather and an intermittent snow-covering. On the whole, the summer climate is somewhat enervating for older children. The autumn months, however, are very fine. The rather mediocre winter climate is partially redeemed by a high ratio of sunshine on the coast; the spring is damp and, on the whole, the least agreeable season, though there are many bright days even in March and April.

Much has been done to make this region a popular health resort; accommodations range from fairly good to luxurious, and are being increased annually to meet a steadily growing demand. The New Jersey coast presents one of the few intelligent attempts in this country to build up a really high grade climatic refuge.

Central New York and Pennsylvania.—This region presents a rolling country, with an elevation ranging from 800 to 1,600 feet, varied at its northern edge by the picturesque lakes of central New York. In summer the lower levels are rather warm, while the winter in southern Pennsylvania ceases to afford continuous cold weather and a permanent snow-covering. The extremes are the Pocono region, which has a fairly cool summer and a steady winter, and the lower Delaware and Susquehanna Valleys, where the summer is apt to be very hot and where the late spring and autumn are the best seasons. Good accommodations, though rather scattered, are increasing. The most important consideration for a prospective resort in this region is the altitude.

Maryland, Virginia and West Virginia.—Here we are on the threshold of the South, and must distinguish between summer and winter resorts. Hot Springs and White Sulphur Springs offer excellent accommodations, but are a little too warm for northern visitors in midsummer, and too near the freezing and thawing point in midwinter. They are best suited to the spring and fall. In the lowlands we find the first really mild winter weather at Norfolk and vicinity, where zero is unknown, but where there is still some snow and considerable frost. This district is also known as a summer resort, but for southern visitors only; for northerners it is, from June to September, decidedly too enervating.

The Lake Region.—Notwithstanding its great extent, only certain sections of the Great Lake Region are of value as health resorts. The Thousand Islands, in the extreme east, have a moderately warm summer and afford good accommodations. The shores of Lake Ontario offer similar advantages; those of Lake Erie are too warm in summer, especially on the American side. Throughout this region the winter months afford very little good weather, the ratio of cloudiness from November to February being the highest in North America. The shores of Lake Huron and Georgian Bay have a cool summer, especially on the Canadian side; the near-by Muskoka Lake region enjoys a fine summer, with a few hot days; the winter is exceptionally changeable, even for America, and northward becomes also very cold. This entire region is to be recommended only from July to September.

The shores of Lake Superior vary according to the exposure. The north shore is relatively cold at all seasons, with a winter that is quite arctic, and affords very limited accommodations. The same remarks apply to the western end, save that there is a lower average of cloudiness in winter. The south shore has a climate somewhat resembling that of the Maine Coast, but colder and gloomier in the winter months. On this side of the lake accommodations are better, but the good season is almost limited to August, as black flies and mosquitoes are troublesome in the early summer, and September is often rainy.

The northern end of Lake Michigan is a little milder on the east side and drier on the west; the accommodations are very good, making this section the favorite summer resort for western tourists. Southward it grows warmer, though frequent lake breezes mitigate the summer heat even in Chicago. The springs near Milwaukee, lying somewhat inland, are much frequented, but are too warm in summer to afford a bracing climate.

None of the lake resorts are adapted to a stay from November to April, inclusive; the winter weather is too stormy, gloomy and changeable, and the raw winds of early spring are even worse than those in New England. Southward, May becomes pleasant, and there is a preponderance of sunny weather almost everywhere from June to September.

The Ohio Valley.—This region has little to offer the health seeker, save the mineral springs of southern Indiana, where the summer is intensely hot, and the winter weather exceedingly variable, with a very uncertain snowfall and heavy rains.

The Upper South.—The southern Appalachians have become very popular, not solely for the treatment of tuberculosis, for which they are only moderately well adapted. The winter weather is unsteady, neither really mild nor cold, and the summer is rather hot for northern visitors, though affording welcome relief to residents of the lower South. The spring and fall are the best seasons in this region. Altitude is very important in summer, when resorts lower than 2,000 feet should be avoided, at the other seasons this factor becomes much less important. Good accommodations are still limited to a few localities, as at Asheville, which is much frequented by tuberculosis patients.

The Lower South.—This region can be recommended only for the winter and early spring; from May to October the weather is exceedingly hot, rainy and malarious; the cooler months are relatively dry, with abundant sunshine. In the lowlands of North Carolina the winter is still moderately cold, with frequent frosts and some snow; in South Carolina and Georgia it is milder, though freezing weather is not rare. Northern Florida and the middle Gulf Coast are almost subtropical, but nevertheless present all the irregularities of the southeastern winter. In fact, this region is better suited to the period from late February until mid-April than to the true winter season, when the visitor is apt to encounter a frequent and perilous alternation of heat and frost, as warm and cold waves follow one another. The lower South presents, in winter, the features of an exaggerated northern April, not uniform balminess, as advertised. In early spring, this climate is rather good; March in Georgia resembles April in Virginia and May in New England, but with less tendency to sudden changes.

The Florida Peninsula.—The commonest mistake is to speak of Florida as if it had one climate, whereas the winters of Jacksonville and Key West differ on the average by 15 degrees, and in their extreme cold by 25 to 30 degrees. At the former place, January resembles early May in New York, with hard frosts more appropriate to March than May; at Key West, January resembles the New York June, and is actually quite tropical, save for a few chilly spring-like days.

The second mistake is to delay the southern tour until the latter part of the winter, say February, and then transport the patient from Boston or Chicago without a break in the journey to Palm Beach or Miami, where the temperature is about 40 degrees warmer than the one he left behind him. Some days after arrival, when the process of enervation is fairly started, the patient is surprised by a norther, with a temperature near the freezing-point, and runs a good chance of contracting a severe cold. An unusual season—the ordinary mixed weather of our Southeast is always called unusual for the benefit of visitors—is apt to leave the patient worse off than before. Fortunately, it is not the rule to return the patient directly home at the end of the far southern season, about April 1, but to travel northward gradually, choosing an intermediate station for the month of April, so as to avoid the inclemencies of early spring in the north.

The third error, a common one, consists in keeping the patient in this increasingly warm and moist climate until April or May. Enervation is the chief danger to be apprehended; it is quite certain to be accomplished by a prolonged residence in this region; for this reason, the absolutely tropical but still changeable winter of Key West is best avoided altogether.

On the whole, in the treatment of disease, the upper South is often to be preferred to the lower South, and this in turn to the Florida peninsula. This rule, of course, admits of many exceptions, but experience will nevertheless bear out the general statement. Furthermore, there is little doubt of the inferiority of our southeastern climate to that of southern California or the western Riviera, its chief merit being its relative accessibility from our eastern cities.

Throughout our Southeast, good accommodations are fairly plentiful, but expensive. Medium priced facilities, as regards both fare and general hygiene, will usually be found inferior to corresponding ones in the northeastern states.

The Bermudas and West Indies.—What has been said of the Florida peninsula applies here even in a higher degree. There is indeed an absence of the sudden changes that characterize the winter on the mainland, but the even, moist warmth causes enervation even more readily. It is worth mentioning, however, that this defect has long been recognized. Bermuda, from December to April, inclusive, is not very warm, the day temperature averaging only about 70 degrees, but the West Indian winter is from 10 to 15 degrees warmer, and therefore absolutely unsuited to the therapy of infancy and childhood.

The Mississippi Valley.—This region is of little value for our purpose. The winter climate is excessively changeable, while the summer, from Illinois and Missouri southward, is very hot and malarious. Almost the only health resort in the section is Hot Springs, Arkansas, where the climate is pleasant only in the spring and fall.

The Great Plains.—When the Great Plains were first settled, much was said about their healthful climate, but we hear little of that today. The Canadian Northwest, however, enjoys a bracing summer. This is also true, to a less extent, of North Dakota and eastern Montana; farther south, the summer climate becomes oppressive, as the moderately low humidity does not fully compensate for the high range of the thermometer. The winter is excessively cold in the north and very changeable everywhere. Altogether, the blizzards of winter and the hot winds and tornadoes of the warmer months render the plains from South Dakota to Texas unsuitable as health resorts. Furthermore, from Kansas southward the dryness is not sufficient to prevent the occurrence of pernicious forms of malaria.

The Rocky Mountains.—In the following account we shall omit the southern Rocky Mountain region, which merits special consideration. In the Canadian Rockies, the summer is very cool and pleasant, while the winter, considering the altitude, is mild and considerably warmer than on the Plains. In fact, it is more like the winter of the New England mountains, except that the snowfall is much lighter. Some winters are almost arctic in their severity, whereas others are markedly tempered by frequent warm Chinook winds. The more uniform cold of the northeastern winter is often absent. In this section, which rivals the Alps in picturesqueness, the railways have furnished good accommodations at a number of points.

Not greatly inferior are the resorts of western Montana and northern Wyoming, notably the National Glacier and Yellowstone Parks, which are open only in summer. Their climate is slightly warmer than that of the Canadian Rockies, and the accommodations are very good. Southern Wyoming, with a somewhat warmer and sunnier climate, does not as yet supply adequate facilities for health seekers.

Colorado does not afford a really cold winter, save in exceptional seasons or at very high altitudes, and the summer, at ordinary elevations, is rather warm, though the low humidity renders even temperatures above 90 degrees quite endurable. Moderate rains, falling mostly in scattered showers, occur from April until September; the precipitation during the cold months is very light, so that there is no slushy snow-melting season in the spring, as in the northeastern hills or the Alps. Good accommodations are readily obtainable in many sections of Colorado, but the eastern foot of the Rocky Mountains ranks highest in popular favor.

In Nevada and Utah—the Great Basin—the dry and rainy seasons are reversed. The winter is less sunny than in Colorado, and brings some rain and snow. From June until October almost absolute drought prevails, converting the country into a dusty desert. These conditions render those states less desirable for health seekers than Colorado, though here also a low humidity compensates for rather high afternoon temperatures. In Utah and Nevada the weather, especially in winter, is far less changeable than on the eastern slope of the Rockies.

The Arid Southwest.—The higher resorts of New Mexico and Arizona afford a moderately cold and very dry winter, an almost rainless and windy spring, moderate heat with frequent showers from July to September, and a wonderfully pleasant and dry late autumn. At altitudes below 5,000 feet, the summer becomes a little too warm; below 3,000 feet the temperature often exceeds 100 degrees, and the winter becomes spring-like. Accommodations at levels of 4,000 to 7,000 feet are rapidly improving at a number of places in New Mexico, so that this state bids fair to rival Colorado in popularity.

The lower altitudes of Arizona afford one of the best warm and dry winter climates, with a great daily range of temperature, but little variation from day to day. The summer, however, is excessively hot, and the humidity is not especially low during July and August, so that the heat is quite intolerable. Good accommodations at the moderately low levels are rare in Arizona outside of Phoenix and Tucson, and the Grand Canyon at 7,000 feet.

Owing to political and social conditions, the fine and mild winter climate of the Mexican plateau is at present unavailable for health seekers. This country, however, remains a promising and almost virgin field for future enterprise.

Southern California.—The southwestern corner of California has one of the finest climates in the world, with only a tendency to drought to detract from its many charms. On the islands the temperature of the rainless summer is continuously spring-like; on and near the coast the summer is varied with a few hot but dry days; inland, as far as the coast range, the summer days are warm, but the nights are cool. In winter, temperatures below freezing are extremely rare, except in the interior; moderate rains fall from November until April; snow is almost unknown. This climate is at its best in the rainy season, for the summer is very dusty, even at the cooler maritime stations. Here, afternoon fogs are frequent. Accommodations are plentiful and excellent, but prices have risen considerably in recent years.

Southeastern California is desert-like, resembling the lowlands of Arizona in its mild and dry winter, and its intolerably hot summer.

Middle and Northern California.—The coast of middle California resembles the preceding in winter, but is a few degrees cooler and far more rainy, though there is ample sunshine between the wet spells;

farther north the winter is still quite mild, but becomes intolerably rainy and stormy, so that it is unsuited to our purposes. The interior of central California is not much colder. There are frequent rains here, but also many sunny days. In summer, the coast of middle and northern California is very cool, windy and foggy, actually feeling colder than the winter, though the thermometer ranges from 6 to 10 degrees higher in July than in January. As we go inland, however, the summer grows steadily warmer, becoming very hot and dry and somewhat malarious in the great central valleys. June to September are almost rainless in central and northern California also, and these months are therefore very dusty.

Middle California offers a good climate for health seekers from November until May, but northern California is too stormy on the coast, and is also rather wet in midwinter in the interior; in the latter, however, the spring months are very agreeable. Accommodations of every grade are abundant along the coast from San Francisco Bay southward, less so in the interior or the northern parts of the state, which are climatically less desirable.

Oregon and Washington.—The coast climate of these states resembles that of northern California, except that it is even stormier and rainier from October until May, with occasional sharp frosts. The summer is cold, damp, foggy and windy, and no longer quite free from rain. This section, therefore, cannot be recommended as a health resort.

The interior of western Oregon and Washington is similar to the coast in winter, with a few really cold days, and occasional snowstorms. July and August are fine, with little rain, some hot days, but invariably cool nights, thus affording one of the best summer climates of the United States, superior even to that of the northeastern mountains. Good accommodations are mostly limited to the larger cities and their environs.

East of the Cascade Mountains the climate is much drier and more changeable, resembling that of the Great Basin. The winter is moderately cold, with some rain and snow. The summer is very dry and sunny, rather hot at low levels, but pleasantly cool at elevations of 2,000 feet and over. Outside of the larger towns there are practically no accommodations for health seekers.

The North Pacific Region.—Except in the sections near Victoria and Vancouver, the north Pacific coast has nothing to offer us. The climate throughout the year is chilly, though not really cold and the weather, except in midsummer, is wet and gloomy.

The interior of British Columbia resembles eastern Washington, but is somewhat colder, being farther north. At high levels we find the cold and bracing climate of the Canadian Rockies, with a heavy snowfall during half the year; at the low levels along the Fraser River, the summer is dry and very warm. Accommodations in this region are still very scanty, except along the Canadian Pacific Railway.

Southern Alaska is too cold and wet for the health seeker, and the facilities afforded by the steamers plying between the northwestern cities and the Alaskan coasts and islands are not well adapted even to such children as might be benefited by a sea voyage.

Foreign Resorts.—With the cessation of the Great War, a number of foreign resorts have again come into favor because of their incontestable climatic merits and superior accommodations. We may therefore devote a few paragraphs to the resorts of western Europe, central Europe, and the Mediterranean region.

Norway and Sweden are known to us chiefly through the popular trip to the North Cape, which involves a rather rough voyage that unfits it for young children. The climate of the Norwegian coast closely resembles that of Alaska. The interior of the Scandinavian peninsula is almost unknown to medical climatologists, though its fine summer, resembling that of interior Maine or New Brunswick, entitles it to some consideration. Accommodations are fair to good, and usually reasonable in price.

The British Isles afford a climate very much like that of the Puget Sound and Vancouver regions, with a somewhat rainier summer, and a very mild winter along the Channel and in western Ireland, where frost and snow are uncommon. These favored localities also enjoy relatively abundant sunshine, which, however, is not saying a great deal, as excessive cloudiness and frequent rains form standing objections to the British climate, especially in the autumn and winter.

Western France presents a climate very much like that of western Oregon. The summer is somewhat rainier, except in the south near the Spanish frontier, where exceedingly popular health resorts have sprung up, both on the coast and in the foot-hills of the Pyrenees. The interior of France has a more extreme climate, and does not offer us anything special, except at certain well known mineral springs, such as Vichy and Aix-les-Bains.

The Atlantic Coast of Spain and Portugal resembles the California coast in climate, but affords good accommodations only at few localities. Madeira and the Canaries somewhat resemble the Bermudas in the winter months, but the summer is far drier and much cooler, so that these islands are good year-round resorts, whereas the Bermudas are exceedingly warm and humid from May to October inclusive.

Central Europe.—The mountains of central Europe have deservedly become the world's favorite playground and health resort; their natural advantages, only in part climatic, have been enhanced by enterprise and no little government aid, so that the visitor is made comfortable in ways of which American resort proprietors know only the veriest rudiments. This region includes southern Germany, Switzerland, Austria, and Czechoslovakia. At medium elevations the climate rather closely resembles that of our northern Alleghanies, but is a little cooler in summer and considerably less severe in winter, when there is an abundant snowfall in ordinary seasons. At high elevations, we have the climate of the Canadian Rockies, with rather more moisture. Certain Alpine valleys are warmed by so-called foehn winds, the prototype of our western Chinook. The southern foot of the Alps must be differentiated from the remainder of this region because of its warm summer and usually open winter: Here we have conditions much like those of the southern Alleghanies, but at a lower altitude.

Spain.—Excepting for its northwestern coast, Spain has a typical Mediterranean climate, with wet winters and dry summers. On the plateau the climate recalls that of Utah and Nevada, with a somewhat milder winter. Along the southern and eastern coasts, we are reminded of interior California by the mild winter, with its irregular rains, and the high temperatures and drought of summer. Accommodations are not good except at a few stations like Malaga and Gibraltar.

Mediterranean France, not including the Riviera, resembles the adjoining coast of Spain, except that the winter is somewhat colder and suffers from frequent high and sharp mistral winds, resembling the northers of our gulf states. This region cannot be recommended to invalids.

The Riviera.—This remarkable strip of coast owes its phenomenally mild winter to the shelter afforded by the Maritime Alps and Apennines, the section from Cannes to Genoa being specially favored. The winter is, however, not quite so mild as in southern California, for there is occasional snow, and the temperature not very rarely falls below the freezing-point. On the other hand, a comparison with the coast of South Carolina, which has almost the same average winter temperature, is very much against the American resort, where the weather changes are much more frequent and extreme. The summer months along the Riviera are not especially hot, and health seekers may find the entire period from October to May enjoyable.

The Peninsula of Italy shows a gradual moderating of the winter as we advance southward from the rather extreme climate of the Po valley and Venice, but the mildness of the Riviera is not attained north of Naples. The interior of the mountainous peninsula has a rather cold winter, with plenty of rain and snow. North of Naples the only good seasons are the spring and late fall, as there is a great deal of malaria from July to October. In southern Italy the winter is pleasant and very equable, but good accommodations are available only in Naples and its vicinity.

Sicily has a winter climate almost identical with that of southern California and can be safely recommended from December until April, inclusive. Malta is still milder, and free from frost and snow, which are not altogether unknown in Sicily.

Algeria affords a number of good winter resorts of two different types. The coastal stations have a California winter and spring, at least until May. Biskra, at the edge of the desert, offers a climate very much like the climate of the Arizona desert lowlands, including the terrific summer heat, the dryness throughout the year, and the scanty rainfall.

Egypt, except in the lower Nile Delta, has a very dry, almost rainless climate, which is at its best from December to March. Hot winds, which are a feature in the spring, are very trying from April to June, then a summer sets in that recalls the most arid districts of our Southwest. The winter temperature resembles that of the lowest levels of Arizona, but the cloudiness is somewhat greater in lower Egypt, where there is some rain in the coolest months.

By way of a summary, we may record the following concise climatic classification of the health resorts mentioned in the preceding pages.

I. Hot and moist. The West Indies, the Florida Keys.

II. Warm and moist. The coast from Charleston to beyond the Rio Grande; Florida except the extreme south; the coast of southern California, the Bermudas, the coast of Portugal and southern Spain, Madeira and the Canaries, Sicily, the coasts of Algeria and Egypt.

III. Warm and dry. Southwestern Texas, the Mexican plateau, the lowlands of Arizona and southeastern California, the Algerian Sahara, nearly all of Egypt.

IV. Very temperate and moist. The coast of California from Santa Barbara to San Francisco, the south Californian islands.

V. Warm temperate and moist. The remainder of the southeastern states, Spain except the extreme south, southern France, Italy. The Spanish plateau is dry in summer, the Mediterranean coasts are moist, but with little rain.

VI. Warm temperate and dry. Moderate elevations in the arid Southwest, the Great Valley of California; the latter is moist in winter.

VII. Cool temperate and moist. The northeastern states, except the mountains, the northern parts of the Lake Region, and the entire state of Maine.

VIII. Cool temperate and dry. Moderate elevations in the Rocky Mountains north of New Mexico and Arizona.

IX. Cool and moist. Nearly all of Canada, Maine, the northern Alleghanies, the northern parts of the Lake Region, western Washington and Oregon, British Columbia; the lowlands and moderate elevations of western and central Europe.

X. Cool and dry. High altitudes in the Rocky Mountains up to the tree line.

XI. Cold and moist. Elevations above the tree line in both continents.

APPLIED CLIMATOTHERAPY

Seasonal Climatotherapy

It is often desirable to give climatic treatment to children who are not actually ill, to employ it as a prophylactic or merely to subject patients to better atmospheric surroundings. In addition, removal to another climate may also be a means of avoiding objectionable home conditions. We may therefore briefly consider what may be called seasonal climatotherapy.

Summer Resorts.—Occasional hot weather is not in itself injurious to infants and very young children, provided the general hygiene as to pure air and clean food is free from reproach. There is no occasion for an especially high infant morbidity during summer even in our large cities, whereas in the country the summer is the most healthful season of the year. Nearly all our rural resorts are beneficial to infants. In fact, babies thrive in localities where adults are oppressed by the heat and humidity. Sometimes, however, a change of air is desirable for infants, as it often is for older children, so that the following observations may be useful.

During the infant's first summer, the seashore is particularly beneficial because of the relatively even temperature and the pure air from the ocean. At this age a moderately high temperature is not objectionable. The somewhat sultry summer of Long Island and New Jersey seems to be the very thing for young infants, who, at such northern resorts as the Maine coast, require protection from the chilly sea-fogs. The Pacific states offer more limited facilities, as their seashore, north of Santa Barbara, is too cold, foggy and windy for infants. The sheltered semi-inland localities are, therefore, preferable. Residents of the middle West will find a fair substitute for the seaside on the eastern, that is the cooler and breezier shores of the Great Lakes. During the infant's second summer, we may choose the cooler seaside and lakeside resorts, as a little climatic hardening will then not come amiss.

As to inland summer resorts, the rather warm lowland stations of the middle states are very well suited to the young infant, but are not sufficiently bracing after the second summer, when the child is able to indulge in exercise. As the summer is the best season for initiating a systematic course of hardening, it is best to select for these months a mountain resort, where the days are moderately warm, but the nights cool. High altitudes are not directly contraindicated even in early infancy, save that very elevated stations are usually too cool for the very young; this applies particularly to the Alps and northern Rockies; in the middle and southern Rocky Mountains, as in Colorado, the summers are quite warm, even at an elevation of 6,000 feet.

Winter Resorts.—In selecting a winter resort it is well to set out with the understanding that no system of hardening is to be inaugurated at this season. Even in distinctly southerly regions, the winter months are characterized by sudden temperature changes, frequent frost and occasional snow. It seems hardly worth while to transport a child to a climate that differs from its native surroundings only by some 5 or 10 degrees in temperature, and by little or nothing in general type.

One point, however, is worth considering. In the Lake Region, the upper Ohio Valley, much of the hilly Northeast, and all of the far Northwest, the winter months afford barely 20 to 30 per cent. of the possible amount of sunshine, whereas the middle Atlantic coast has 50, Florida 60, and Colorado and southern California have 70 per cent. Removal from the Lake Region to Long Island or New Jersey involves far more than the difference of a few degrees in temperature, and cannot fail to be beneficial, especially to children below the school age, who at home are too often kept indoors by bad weather.

Aside from the consideration just noted, we need regard only such winter climates as have a decidedly spring-like temperature and plenty of sunny days. Among these southern California ranks first. There the winter is rather finer than the eastern October. It affords bright sunshine two-thirds of the time, an agreeably bracing temperature, and usually sufficient rain to lay the dust. The winter climate of the Riviera and southern Italy, with barely 50 per cent. of sunshine and a good deal of rain, is somewhat cooler. This climate involves a very mild degree of hardening, as the average temperature is decidedly April-like. Both the regions mentioned, however, are superior to our own Southeast, where, from North Carolina to northern Florida, the weather is too changeable and in the extreme south somewhat enervating. This section has, on the other hand, the great merit of accessibility from our great eastern cities. The winter visitor to this region must take along both light and heavy clothing, and be prepared to adapt himself on short notice from June to March weather.

The cold winter resorts, especially such subarctic winters as prevail in our northern mountains and in most of Canada, are not suited to infants and young children, who stand severe cold badly. The dry, sunny, and only moderately cold winter of Colorado and New Mexico is less objectionable, and is certainly beneficial to older children who are in need of hardening. Experience drawn from the climatic treatment of adults should not control our procedure when we come to handle very young patients, whose requirements are different.

Spring Resorts.—The principles guiding us in the selection of winter resorts apply also to early spring. Such subtropical regions as southern Florida and Egypt become too warm by the end of March, but most of the remaining winter stations are really at their best in March and April, and are particularly to be recommended as intermediate stopping-places, before returning the patient to his northern home, where settled spring weather often does not set in until May.

It is not easy to strike a balance between the respective merits and defects of seaside and inland spring resorts. The former are less rainy, paradoxical as it may seem. They are cooler and windier, but far less subject to sudden temperature changes. Probably the semi-inland resorts, such as the lowland localities from New Jersey to North Carolina, as well as southern California away from the coast, are most desirable of all.

Autumn Resorts.—There is little occasion for going into details in this connection. Since the autumn climate of most of the United States and Canada is all that could be desired, not much can be gained by a change of air. It is sufficient to note that September is a typical summer month southward, whereas northward November becomes somewhat wintry, so that these months, in the regions mentioned, may suggest the advisability of removal to a more temperate region. In general, it may be said that a change of climate is rarely indicated at this season of the year.

SPECIAL CLIMATOTHERAPY

Climatotherapy belongs in the main to the field of general, as opposed to special therapeutics, so that the general condition of the patient must guide us even in the treatment of specific disease. At the same time, we are often enabled to direct our measures toward a definite symptom or syndrome, so that different diseases call for management along different lines. We may begin with the treatment of constitutional disorders.

Malnutrition.—Under this head we include imperfect convalescence following acute or chronic disease. The patient's weight is below normal, his resistance to cold is lowered, the visceral functions are more or less impaired, but there is no evidence of any organic or infectious disease. These patients at first react poorly to hardening procedures, and do best in a rather warm climate, where there is plenty of sunshine, permitting some moderate outdoor exercise. For the winter season, California, the Riviera, or northern Florida afford the best surroundings. Southern Florida and the Bermudas are too enervating for most of these cases, and are suited only to a temporary stay for greatly enfeebled or very young children. For the summer, we should avoid the more sultry seaside and inland resorts, as well as very elevated and Alpine mountain stations. The New England coast and the colder Great Lakes resorts suit many cases, but the mountains of New York and New England are best of all, even for the very young. These patients are greatly benefited by removal to the middle and south Atlantic coasts during the uncertain and often inclement early spring months.

Rickets.—Here we encounter a highly specialized nutritional deficiency, which requires management differing decidedly from that adapted to general malnutrition. Many rachitic children are fat and tolerate low temperatures fairly well: it is evident that these can be subjected to a more strenuous regime.

It is generally admitted that the lack of fresh air is a predisposing factor in the etiology of rickets. Outdoor life, therefore, constitutes an important element in treatment, so that it is always helpful to remove the patient from a wet and gloomy climate. High temperatures are undesirable, because they tend to enervation, thereby failing to contribute the hardening that is part of the treatment of rickets. In selecting a climate for the winter and early spring, abundant sunshine and a moderately low temperature are the prime desiderata. These are readily obtained on our eastern coast from New Jersey to Virginia. The South Atlantic coast is too warm, California too equable, and the interior of the South too changeable and not sufficiently sunny. These children can be taken out of doors at temperatures far below the freezing point, though very young patients, especially infants, require shelter from high winds.

In summer, rachitic children invariably do best at rather cool resorts. The coast of southern New England ranks first in this regard, the Maine coast standing a close second, except for delicate subjects. The colder parts of the Lake Region and our eastern mountain resorts also suit these cases well. Colorado is fairly good for such children as are not excessively anemic, but the high Alpine stations and the Canadian Rockies afford a climate that is too strenuous for many. Some hardening is, however, essential, and low-lying inland resorts should be avoided.

Anemia.—Most cases of anemia in children are merely phases of the two preceding affections, for which the climatic treatment has just been discussed. The severer grades of anemia, however, call for some modifications. We have already discussed the stimulating effects of altitudes on the hematopoietic system. Opinions are divided as to sending anemic children to high elevations. Some authorities consider this stimulus the very thing to be desired, sending their patients to the highest available resort. In practice, however, this method does not always work out well; this is particularly true of elevations above 3,000 feet, where many patients suffer from nervous irritability and insomnia. On the other hand, many mild cases of anemia, with more than 70 per cent. of hemoglobin, undoubtedly do well at high altitudes, whereas the severest types, with less than 50 per cent., should undergo at least preliminary treatment at levels below 3,000 feet and in rather warm climates, as hardening is not advisable to begin with.

The Rheumatoid Diseases.—This miscellaneous group, so diverse in pathology, may be treated under one heading, so far as concerns climatic treatment. It is an everyday experience that cold and dampness affect these patients very unfavorably; the indication, therefore, is removal to a region that is both dry and warm, the latter being the more indispensable, since the patient is not able to take much exercise.

In winter these cases do best in subtropical and arid climates, such as is found in Egypt, away from the coast, and in the lowlands of Arizona and southern California. South Florida is decidedly a second choice. Most of the other subtropical stations have a high humidity, and sultriness is not desirable, as tending to enervation. In summer, many desirable climates afford opportunity for balneological treatment. Among these may be mentioned the hill country from central New York to Virginia, the lesser elevations (4,000 to 5,000 feet) in the Rocky Mountains, and the mountain regions of central and western Europe. Owing to the impediments to muscular exercise, decidedly warm climates are well tolerated by rheumatic children, provided the humidity is reasonably low. Seaside and lakeside resorts should be avoided, even small lakes, especially in forested regions, which are the source of much dampness during the night and early morning. Low valleys are also invariably damper at night than plateaus and mountain slopes.

Nephritis.—The chronic forms of nephritis form an attractive and profitable field for climatotherapy; few other diseases show so great a response to removal from a severe to a genial region. The indication consists in the avoidance of cold, especially damp cold. It should be our endeavor to spare the diseased kidneys as much as possible by promoting gentle and continuous diaphoresis, and the best diaphoretic known is warm and dry weather.

For the winter, such resorts as southern Arizona and Egypt rank highest, but since a moderate humidity is not objectionable, southwestern California, Bermuda, Madeira and the warmest Mediterranean stations answer our purpose well. Our South Atlantic coast and the Riviera are somewhat inferior to the above, as they occasionally experience spells of wet and cold weather. They are better suited to the transitional season of early spring. We should avoid returning nephritic patients to their bleak native climate before settled spring weather has arrived, say mid-April in Washington and Cincinnati and early May in Boston and Chicago.

In summer the problem is easy. Any warm and moderately dry climate is suitable. The seaside and the shores of the Great Lakes are objectionable only where fogs and chilly spells are frequent: such localities as the coast of New Jersey or the west shore of Lake Michigan are very good for young patients. As to high altitudes, the opinion of most authorities is adverse. This does not, however, apply to children native, for example, to Colorado, who are accustomed to high altitudes. Moderate elevations seem to be unobjectionable provided the temperature is fairly high.

The climatic treatment of chronic pyelitis and pyelonephritis is very similar to that of Bright's disease, but a rather high temperature is still more necessary, in order to spare the renal functions.

Diarrheal Diseases.—The relation between these diseases and hot weather is less intimate than was formerly supposed; nevertheless, there is no doubt of the predisposing influence of heat and a high percentage of humidity in favoring the chief exciting cause, namely, the putrefaction of milk and other food. If the food supply is kept up to a high standard, the incidence of diarrheal diseases can be kept low even in the hottest climate.

If, on the other hand, we are confronted with a case of so-called summer diarrhea, climatic treatment, when given in conjunction with the necessary dietary correctives, becomes invaluable. As has been suggested, it is not necessary to remove the patient to a much cooler climate; all that is needed is a rural locality where the nights are not oppressive. In fact, a resort only a few miles outside of the city limits may be perfectly adequate. Of course, transportation to a really cool mountain station will be more rapidly effective, often curing the patient in a few days.

The more chronic forms of diarrheal disease, which are relatively common in older children as well as infants, require treatment along more strenuous lines. Even for very young subjects, a decidedly cool summer climate is desirable; still more for older children, who should preferably be sent to some mountain resort of northern New

York or New England, with the Maine coast and northern Michigan as second choice. The lower levels of the middle states, as well as the shores of Long Island and New Jersey, are too warm and sultry in July and August for the best results. More important than climate is a proper dietary, and in selecting a health resort for intestinal cases, the medical adviser will have to consider both factors, the second being generally the more difficult to determine; this accounts for the popularity in the past of western and central Europe, where the accommodations and fare were effective auxiliaries to the agreeable summer climate.

Respiratory Diseases.—Chronic bronchitis without a tuberculous basis is not rare in childhood, being often found in connection with rickets and the exudative diathesis. It is highly amenable to climatic treatment. A mild and moderately humid climate is sure to benefit these cases; thus, we may select southern California or the Riviera in the winter and early spring, a good second choice being our South Atlantic coast, excepting south Florida. A little hardening is not out of place in these cases, so that the warmest winter resorts are best avoided. In summer these children do best at the seaside, preferably north of New Jersey, which is slightly enervating, especially to older children. Dry inland climates and dusty regions are injurious to these patients.

Patients with bronchiectasis are to be treated similarly, although many authors recommend a dry climate, especially if occasional showers prevent excessive dustiness, as in the summer in Colorado and New Mexico. There is no doubt that many patients are benefited by a climate of this type. We must not forget, however, that much depends on whether we wish to render the bronchial secretion more viscid or more fluid, and that the former is favored by a warm and dry climate. We should likewise remember that in the northern winter we spend much of the day and all of the night indoors, in an artificially warm and very dry climate, which has proved by experience not to be beneficial to bronchial trouble. The main indication seems to be a pure, rather moist air, fairly genial in temperature, free from dust, and with ample sunshine to encourage life out of doors.

The above recommendation applies equally to chronic catarrh of the upper air passages. Children affected with the exudative diathesis, who suffer from a tendency to coryza and adenoid growths, do best in a warm and moist atmosphere; even a somewhat sultry climate may be tried in these cases, especially in very young children, who may be referred to subtropical Florida or Bermuda in winter and to the Middle Atlantic coast in summer.

No fact in climatotherapy is better established than the harmfulness of very dry and especially dusty climates in chronic non-tuberculous respiratory disease.

Unresolved and interstitial pneumonia and prolonged empyema often improve rapidly in response to a change of air. We should begin with a rather relaxing climate, especially in treating very young patients, but must not continue this too long. A decidedly bracing atmosphere, such as we find in the Carolinas in winter, New Jersey in the late spring, and the northern mountains in summer, is valuable as an after-cure, particularly in empyema, when suppuration has ceased and increased expansion of the compressed lung is desired.

Pertussis.—Confronted with the doubtful efficacy of the specific treatment of pertussis, the practitioner is compelled to resort largely to palliative remedies, of which pure air is the best. This presupposes a large proportion of fair weather. Many children are deprived of relief by an inclement home climate, and require removal to more genial surroundings during the cold season. In these cases a very mild climate is demanded only for infants and young children; for older children the coast of New Jersey or Long Island is sufficiently warm and sunny; next to these may be placed the mountain resorts from the Virginias southward. Extreme dryness is almost as objectionable as an excess of rain and cloudiness. A change of climate is also valuable in those cases in which the characteristic cough persists for weeks and months after the attack of pertussis has run its course; here the indications are similar to those noted for chronic bronchitis.

Hay-fever.—Autumnal hay-fever is not rare in older children, who require the same treatment as adults. As specific methods are still on trial, our most effective procedure for the present consists in removal to an immune region. The required elevation, to escape the ragweed, which is chiefly responsible for autumnal hay-fever, is about 1,500 feet in northern New York and New England, and at least 2,000 feet in the Catskills and Massachusetts. In some cases various resorts must be subjected to the test of individual trial, until the right locality is found.

As to the treatment of the vernal type of hay-fever, climatic treatment has not yet passed the empirical stage.

Chronic Heart Disease.—We must set out with the understanding that the line between compensated and uncompensated heart lesions is less easily drawn in children than in adults; thus the former are in more need of periodic supervision, the more so because control of exercise and avoidance of undue strain are difficult to enforce at an early age. Fully compensated mitral cases require chiefly to be guarded against enervation, so that an important factor in treatment is the selection of a stimulating summer climate, with special regard to cool nights. Moderate elevations are quite suitable, though altitudes above 3,000 feet should be avoided by patients habituated to low levels.

Unstable compensation, as well as disease of the aortic valve, requires more careful handling. These cases are benefited during the winter months by removal to a moderate but not enervating climate, such as is furnished by southern California, the Riviera, and less adequately by our southeastern states north of Florida. The subtropical climates are too enervating. In summer we may handle these cases somewhat as we do the compensated ones, but with a preference for very moderate altitudes, such as are found in our northeastern mountains.

In cardiac insufficiency a restful regime is essential. We are therefore restricted to rather warm climates, where muscular activity may be dispensed with, such as southern Florida or the warmest Californian and Mediterranean stations for the winter and early spring, and the Middle Atlantic coast during the warm months. Similar treatment is called for in congenital heart disease, especially if cyanosis is present, and the same is true to even a greater degree in the presence of pericardial adhesions. For the graver forms of heart disease it may be advisable, when circumstances permit, to urge permanent removal to southwestern California. This is one of the few regions that enjoys a good climate the year round. Most mild winter resorts are oppressively hot in summer, whereas most suitable summer resorts have a winter that is too bleak for severe cases of heart disease.

The Neuroses.—Nervous exhaustion is frequently encountered in children, especially at the school age, when it is particularly apt to follow severe attacks of one of the infectious diseases. This condition should have mild but not enervating treatment to begin with, followed about a month later by a removal to a decidedly bracing climate, such as New Jersey in winter and the northeastern mountains in summer. Similar treatment is indicated in the enervation due to having lived in a tropical or subtropical climate, except that it is often advisable to cut down the preliminary rest cure. These cases, however, cannot be treated according to a general rule, but should be judged individually. Good preventive work can be accomplished by sending southern children to some northern resort yearly, as soon as the steady hot weather sets in.

There is considerable diversity of opinion as to the methods and the degree of strenuousness to be pursued in hardening. Should this treatment be regarded as a prophylactic or therapeutic procedure against enervation? In general, it appears that an appropriate change of climate is the most easily applied means of hardening, as it can be adapted to the individual patient with considerable nicety, and readily amended to suit a change of seasons or other conditions. Abrupt methods of hardening, still frequently adopted, such as the removal to an extremely cold climate, or the provision of insufficient clothing, are mentioned here only to be condemned.

Persistent chorea is often benefited by a climatic treatment similar to that outlined for nervous exhaustion. The same may be said of the after-treatment of poliomyelitis. In both these diseases the ability or inability to take outdoor exercise must be considered individually. Such consideration will determine the respective selection of a bracing or a very sedative climate.

Neuralgic affections, which are notoriously aggravated by dampness, often require a change of climate. Consequently, removal to a dry region is likely to be beneficial. We should avoid the seashore, especially in spring and early summer, as well as the heavily wooded mountains of our eastern states. Colorado and New Mexico afford a climate that is not excessively cold in winter or extremely hot in the summer, and are worth a trial in carefully selected cases. It is well not to set too great store by a change of climate. We now understand that neuralgia is usually a mere symptom of a general or local infection which may not be influenced by physical therapy, so that climatotherapy in such a case is likely to score a failure.

Skin Diseases.—Many children who suffer from diseases of the skin can be benefited by a change of climate. Some procedures are obvious, as removal southward for winter eczema, and transfer to a cool region for prickly heat. Not so well known, however, is the fact that winter eczema is aggravated by high winds and a low humidity, so that its victims are relatively numerous on the immediate sea-coast and on inland plateaus, and may be relieved in damper localities, such as the Lake region or the southern Alleghanies.

Ichthyosis, as is shown by its seasonal variation, is benefited by transfer to a warm and moist climate, and becomes worse in cold and dry situations.

As to the exposure of the skin to direct sunlight, employed in heliotherapy, it may be noted that distinct benefit is claimed in psoriasis. In general, however, we cannot deny its injuriousness. Severe sunburn after undue exposure may occur from early spring on through the summer. Such exposure is certain to produce intense dermatitis, unless the skin of the patient has become gradually accustomed to the powerful chemical action of direct sunlight. It is therefore evident that this agent must be employed with caution at all times in warm climates and throughout the summer in more temperate regions, more especially at high altitudes, where the actinic rays are not mitigated by passage through the dense lower atmosphere.

Scrofulosis and Lymphatism.—Chronic glandular hypertrophy of non-tuberculous origin is often benefited by climatic treatment, which treatment should consist essentially of gentle but prolonged hardening. For scrofulous children most authorities recommend the seashore, preferably in rather cool regions, such as the Middle Atlantic coast which is quite mild enough during the winter months, and preferable to the South Atlantic and Californian litoral. In summer we do well to transport the patient to the shores of northern New England or the maritime provinces of Canada; at this season the seaside is not quite so essential, and the cooler localities on the Great Lakes or in the northern Alleghanies are a good second choice. The essential requirements are the absence of sultriness, a high ratio of sunny days, and the opportunity for an almost unlimited outdoor life.

High altitudes have not proved especially beneficial in infantile scrofulosis, so that such regions as Colorado are inferior to those suggested above. The winter climate of the interior of the northeastern states is too severe for very young subjects. There is too much zero weather and too much cloudiness to afford a sufficiency of outdoor life. In the case of older children, however, these disadvantages are of less moment and may usually be disregarded.

Tuberculosis.—Climatic treatment is no longer regarded as the most important element in the management of tuberculosis. The best results, however, are achieved with the aid of a suitable climate, so that this treatment proves a valuable adjunct. Although relaxing climates are unquestionably injurious to tuberculous patients, it is not essential to go to the opposite extreme. In fact, the routine recommendation of a subarctic winter resort has been overdone, and there is no question as to its unsuitability for young children. However, such territory as that ranging from southern New England and New Jersey westward through the Ohio Valley, in which the winter temperature averages around the freezing-point, and in which there is more or less slushy conditions under foot, is less desirable than the continuously snowed up sections farther north, or the milder but still bracing climate of the upper South. In fact, the greater portion of the Lake Region is objectionable, because of its high ratio of cloudiness from November until March.

The fact is, that tuberculous patients have been observed to do about equally well in semi-southern winter resorts as in the subarctic climates of the White Mountains and Adirondacks. This is especially true of young children. For the ages beginning at puberty and thereafter the extreme hardening regime of the far North is, on the other hand, quite effective.

For the summer months, the necessity of a decidedly cool climate is now undisputed. Tuberculous children do best in Canada, northern New England and New York, the cooler parts of the Lake Region, and the northern Rocky Mountain resorts. Our choice between the mountains on the one hand, and the sea and lakeside on the other, must be determined individually, and, as stated below, according to the type of tuberculosis present.

The majority of tuberculous children exhibit the surgical forms of the disease, the lymph-nodes and bones being the organs chiefly affected. These types of tuberculosis, including the group known as tuberculous scrofulosis, require climatic treatment similar to that previously outlined for pyogenic scrofulosis, and do best at cool seaside resorts enjoying a high percentage of sunshine. Heliotherapy, or exposure to direct sunlight, has been extensively employed in this group of cases. Satisfactory results have been claimed, though the superiority of this method is not yet firmly established and requires further trial. The initial exposure should not exceed five to ten minutes. Prolonged treatment should not be attempted until the patient's skin is thoroughly tanned by the sun; otherwise a painful dermatitis will ensue. We may again note that the action of the solar rays is much more intense at high elevations than at the sea-level.

Sufficient time should be allowed for a positive cure to take place. The few months formerly granted are quite insufficient, and a minimum of one year is none too great. This error makes all the older statistics worthless as a measure of what can be effected in tuberculosis by climatotherapy, and its elimination fully accounts for the better results achieved in recent years.

Pulmonary tuberculosis of the adult type is rare in young children, but becomes increasingly frequent toward puberty. The climatic treatment of phthisis in older children is the same as that of similarly affected adults, namely, to subject the patient to the most intense climatic hardening that he will stand. Inland stations which are more or less elevated, with the lowest attainable temperature at all seasons, are, as a rule, the most beneficial. A few young children cannot stand the intense rigor of our northeastern mountains. For these a milder but not warm winter climate is better suited; for example, Colorado, New Mexico, or the higher points in the southern Appalachians. Time is a factor in pulmonary, even more than in surgical, tuberculosis. A trial of a few months is merely in the nature of a reconnaissance, a preliminary test of the efficiency of climatotherapy in the case under consideration. For a real cure a space of at least two years should be allowed. Phthisis in children offers a very grave prognosis in any case, as the young organism resists the invasion of the tubercle bacillus with relative feebleness, while the danger of rapid extension, or relapse after apparent cure, is much greater than in adults.

Great caution must be exercised with regard to the diagnosis of incipiency. Unless this is corroborated by some months of clinical observation, as well as by *x*-ray studies, it is better, regardless of the history and physical findings, to regard supposedly early cases as if the disease is well on in the second stage. This is to a large extent true of adults and still more so of children, and influences the probable duration of treatment very materially.

Other forms of visceral tuberculosis, such as involvement of the kidneys or peritoneum, are to be classed with surgical tuberculosis and treated accordingly. Rapidly progressing pulmonary disease is not likely to yield to climatotherapy any more than to other treatment, which is apt to be as successful at home as elsewhere.

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CHAPTER XI

HYGIENE OF CRIPPLED CHILDREN

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One of the most interesting and profitable of the newer sociological movements is that which has to do with the care of cripples. There has been some special provision for the hospital care and training of adult cripples, but in large part the movement is one which has to do with the care of children.

The problem of providing care for cripples is a much larger one than at first appears. We find that such provision involves much more than simply to provide asylums for those crippled and deformed individuals whom we occasionally see on the streets and in other public places. Not only do many of our cripples belong to the shut-in class, known to few save their families and friends, but there are hundreds sick at home or in hospitals suffering from acute or chronic deformity producing diseases. It is not generally appreciated how many infections there are which, in the absence of special care, lead inevitably to crippling or deformity. We have found that not only may many of such diseases be cured, but that deformities which have existed for some time may be corrected or ameliorated by adequate hospital care. It is true also that many of those individuals who are largely or wholly dependent for their very existence upon the ministrations of those about them can be restored to usefulness and independence by combining special education or training with institutional care. The solution of the whole problem becomes a task of some difficulty, to be sure, but it is one which carries with it very great rewards. It is this feeling, no doubt, which has influenced so many people of wealth and influence in this country and elsewhere to offer opportunities for the care of such children.

From the viewpoint simply of loss and gain it has long been considered that the education and training of normal children is a profitable undertaking for the state. Considering therefore how much larger a proportion of the crippled children, unless given the necessary training and medical attention, become dependent or are made the objects of special care, it is evident that the state is simply using ordinary business foresight in erecting suitable hospitals and providing the education that will make these cripples partially or wholly independent and self-supporting.

While much that has so far been accomplished in this country has been done with private funds, there are many reasons why the care and education of crippled children is naturally a state function. It has long been considered that the education and training of normal persons is a profitable undertaking for the state, but it is certain that a much larger proportion of those who are crippled become dependent if not made the object of special care. Economically, therefore, the state is simply using ordinary business foresight if by suitable hospital care and education these patients are treated and trained so as to become partially or wholly independent and self-supporting.

"The effort to provide properly for the care and education of crippled children has probably been more energetically exerted in Germany than in any other country in the world. The movement started early with the foundation of the Munich institution in 1832, and since that time the homes have grown steadily in number and the standard of work has been raised higher and higher.

"Furthermore, this movement in behalf of the cripples has been an intelligent and concerted one. For several years there has been a national society for cripple care, the Verein für Krüppelfürsorge. Since 1900 there has been published a year book on the subject, the Jahrbuch der Krüppelfürsorge; since 1908 there has been issued an excellent quarterly journal dealing with the work, the Zeitschrift für Krüppelfürsorge. By these means the persons in Germany having in charge the care of cripples have been kept thoroughly informed regarding improvements in methods, and there has been free and constant interchange of experience. This feature of the German work should be especially suggestive to those in America engaged in the same field.

"The greatest possible aid to the development of the work in Germany was derived from a census of all the crippled children in the Empire in 1906. Individual data regarding each cripple under 16 years of age were recorded and tabulated. The results and findings have been excellently presented by Biesalski. In all there were found 75,183 crippled children under the age of 16. In relation to the population this made an average of 14.8 crippled children under 15 years of age to each 10,000 of population of all ages. Calculated on the basis of proportion to the total population of children within a similar age group, it is found that there were among each 10,000 children 35.73 crippled children. That is among the juvenile population 0.36, or nearly four-tenths of 1 per cent., were crippled."*

There has been but little conception in the United States of the scope of this work. Within the past few years several statistical studies have been made. Some of these were definite "Surveys" to determine as accurately as possible how many individuals there are who require special care of the nature above described. Several years ago the writer, after extensive correspondence and after having dealt personally with nearly 2,000 cripples in Nebraska, came to the conclusion that there was in this State approximately one cripple to every 250 of the population. Supposing that the figures for other areas are nearly the same, it may be assumed as a fair estimate that there is a proportion of 3,000 cripples to the million of population. Upon this basis the number of cripples in the various states may be estimated about as follows:

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* Douglas C. McMurtrie, M.D., The Care of Crippled Children in Germany, New York Medical Journal (Feb. 21, 1914).

Alabama	6,414
Arizona	612
Arkansas	4,722
California	7,131
Colorado	2,397
Connecticut	3,342
Delaware	606
District of Columbia	993
Florida	2,256
Georgia	7,827
Idaho	975
Illinois	16,914
Indiana	8,100
Iowa	6,672
Kansas	5,073
Kentucky	6,867
Louisiana	4,968
Maine	2,223
Maryland	3,885
Massachusetts	4,098
Michigan	8,430
Minnesota	6,225
Mississippi	5,391
Missouri	9,879
Montana	1,128
Nebraska	3,576
Nevada	243
New Hampshire	1,290
New Jersey	7,611
New Mexico	1,081
New York	27,339
North Carolina	6,618
North Dakota	1,731
Ohio	4,301
Oklahoma	4,971
Oregon	1,913
Pennsylvania	22,995
Rhode Island	1,626
South Carolina	4,545
South Dakota	1,749
Tennessee	6,562
Texas	11,688
Utah	1,019
Vermont	1,065
Virginia	6,183
Washington	3,423
West Virginia	3,663
Wisconsin	6,999
Wyoming	435
Total	259,754

[The above estimate does not take into account the rapidly growing number of boys injured on farms and in the industries.]

In several areas the figures are undoubtedly larger because of recent extensive epidemics of infantile paralysis. It is in this class of patients too that institutional care is especially needed and especially effective.

Just recently in a territory comprising four counties of northern Ohio a careful study has been conducted. The names and addresses of a sufficient number of patients have been secured to show that there is, in that area, one crippled child requiring hospital care to every 450 of the population. If these figures are even approximately correct the inadequacy of the facilities for providing such care in this country becomes at once apparent. The total facilities for hospital care and education of cripples in the United States can decidedly be no more than 1 per cent. Biesalski, who has already been referred to, estimated in 1912 that, even with the advanced work being done in Germany, there were in that country only 3,000 beds for the care of the 100,000 cripples who had been located by an official census. In this country the provision of care for such children has been only partially begun. Even in Nebraska, where there is a central institution for the care of

150 children at one time, and bearing the record in mind of having cared for nearly 1,500 patients in twelve years, there are still hundreds of crippled children who have not been reached. In 1922 the Nebraska Orthopedic Hospital has cared for nearly 3000 patients in seventeen years.

Some of the City Dispensaries are doing splendid work for the care of the ambulatory cases. This is especially true in districts where special schools are provided for the crippled children. Here the treatments can be administered, plaster casts applied and reapplied, and braces put on. In such ways great good is accomplished. At present, however, this work is reaching a very limited number. It is the impression of the writer that complete institutional care should be provided for many of those who are now being treated in dispensaries alone.

In Philadelphia "The Widener Memorial School for Crippled Children" is demonstrating what may be accomplished by the ideal institution. It is the aim and the achievement of this school to accept for treatment and education children who are physically dependent, and convert approximately 100 per cent. of them, including even those who cannot be restored physically, into entirely independent and self-sustaining individuals. In other words, even those patients who remain permanently crippled or physically handicapped may, by special training, be restored to usefulness and made fit to support themselves.

It is our purpose to have practically all crippled children treated and trained in institutions based upon the principle of the Widener School. Of course there are different methods of working it out. The superintendent of the hospital in which such patients are treated is, in general, better qualified than anyone else to suggest or direct the education or training of his patients. In every case, however, the institution is preferable to the home, which lacks not only most of the facilities for special care but also the discipline and training so necessary for the abnormal child.

The ideal method of caring for crippled children, it has been declared, is the State Institution in which hospital care and special educational opportunities are combined. This is not to be understood as a criticism of the privately endowed institutions, who have set an example, without which it is doubtful if the States even now would have made provision for this class of dependents. In the first place, the resources of the State should be behind any effort to secure the independence of its citizens inasmuch as the State itself, directly or indirectly, is called upon to bear the burden of all those who are later unable to take care of themselves. The hospital which is also a school is also to be preferred to the present method of trying to make up in schools afterward the ground which the patients have lost during their period of treatment. The experience of Nebraska, as well as other places, shows definitely that with but few exceptions these children with special teachers can keep step with or even make more rapid progress than normal children in the public schools.*

A great deal has been said and written about the necessity for special institutions and a staff of specially trained individuals for the hospital care of these children. It has been the experience now of several institutions that the provision of such facilities to the extent of providing funds and training nurses and other employees for such work, is not as difficult as is commonly supposed.

The Nebraska Orthopedic Hospital was opened for the reception of patients Oct. 1, 1905. The first official biennium closed Nov. 30, 1906. During the first 14 months 108 patients had been received at the institution. The next legislature, before whom an accurate showing was made, not only of the work already accomplished, but of the patients then in the institution and of other candidates for admission for whom no facilities had been provided, responded at once with an emergency appropriation for immediate use considerably larger than the one granted for the preceding biennium, the total amount being in the neighborhood of $50,000.

During a period comprising nearly four years (1905–1909), the experiment of caring for the crippled children of Nebraska was worked out to the extent of providing adequate hospital care and beginning the educational work. Much of the credit for what was accomplished during this time must be given to Hon. H. M. Eaton, chairman of the board of public lands and buildings, who had for many years prior to his election to this office been associated with the public and normal schools of this state. Mr. Eaton was, and has always been since, very enthusiastic in his support of this work. He was ably seconded in his efforts by Hon. A. Galusha and by Hon. George C. Junkin, who were successively secretaries of state, Hon. Peter Mortensen and Hon. L. G. Brian, state treasurers, and Hon. Norris Brown, since United States Senator from Nebraska, who was attorney general. Except for the intelligent sympathy and the enthusiasm of these men, the initial success and development of our institution would have been impossible even with the appropriations made for our work.

One of the principal matters before the legislature during the session of 1913 was the passage of a law to establish and regulate the affairs of a new Board of Commissioners for State Institutions. This new board was provided for by a constitutional amendment adopted by the people of the state about two years before. Legal provision having been made for the organization, powers, and duties of this new board, Gov. John H. Morehead carried out the intent of the law by appointing as its members Ex-Gov. Silas A. Holcomb, Mr. Howard A. Kennedy and Mr. Henry Gerdes. Thus a non-partisan board of Commissioners was put at the head of all state institutions, including the Nebraska Orthopedic Hospital. This plan is still operative.

In some states, perhaps in many, no special effort has been made to resort to political methods for securing the necessary appropriations, because those most interested have expressed themselves as unwilling to "mix in politics." The lesson learned by Nebraska is that members of the legislature and state officers have been the best friends of the institution, quick to appreciate the possibilities of this work, as well as the needs of the patients, and that without their sympathy and support in this, as in any other public work, success would have been absolutely impossible.

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* H. Winnett Orr, M.D., The Industrial Education of the Crippled and Deformed, American Orthopedic Association (June, 1912).

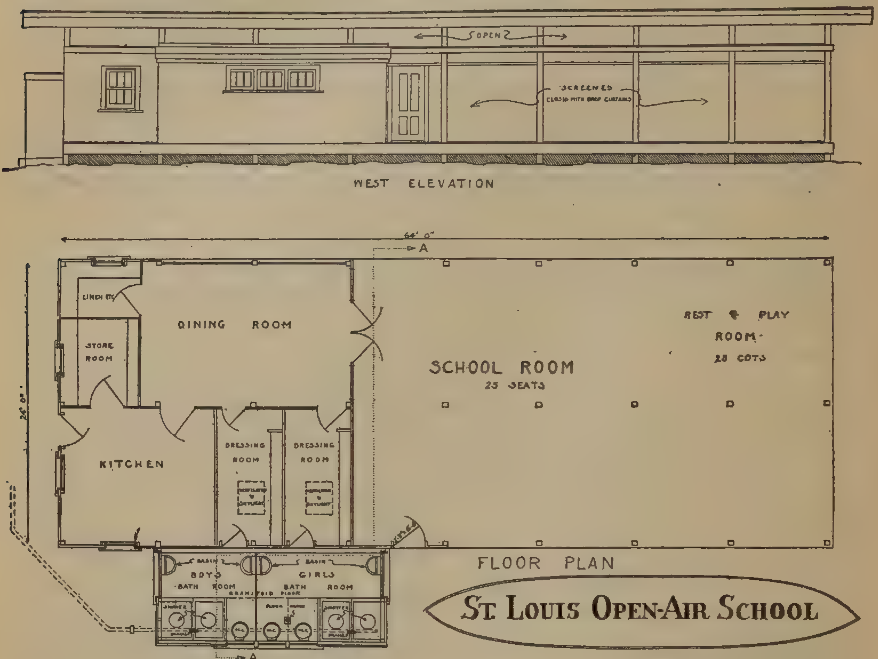
In the establishment of any institution for the care and education of cripples, certain fundamentals must be considered. The hospital buildings should be modern fire-proof structures, consisting of small wards rather than private rooms, containing substantial sanitary and dietary facilities. Elaborate furnishing and equipment are not necessary. Good work is of course being done in institutions almost without buildings and equipment. These act upon the theory that reasonable physical restoration of the patient is all that is necessary and that everything else must ultimately be accomplished by the patient himself. Fundamentally this theory is sound but practically it does not work out. Crippled children are corrected and others saved from deformity producing diseases through the splendid care they receive in general hospitals, but when they leave the hospital they are even more dependent, from a sociological standpoint, than when they were admitted. Many conditions require hospital care for a long time. Children with tuberculous spine disease or with hip-joint tuberculosis quite commonly remain in the hospital from one to several years. Such children, after being restored to a place in society, can scarcely be expected to make up the educational training which they have missed. It is our belief that such education and training should be available during the period of hospital care. The periods during which patients in Orthopedic Hospitals are completely incapacitated are relatively short. When restored to some activity they suffer from idleness as much as normal children. Occupation of some kind, performed under proper supervision, not only does no harm, but can be made to do them a great deal of good. We have repeatedly seen children who come to the hospital one or more grades behind in their school work, complete, during their hospital residence, not only the grades which they would normally have covered during the same period, but extra grades as well.

In every city of 10,000 people or more, provision should be made, either in a special school or a separate department in an existing school building, for the care of crippled and tuberculous children. The two are grouped together for the reason that in any considerable number of crippled children a percentage of one-fourth to one-third are tuberculous. For a considerable number of such children, tuberculous or otherwise, the so-called open-air school will also be highly desirable even if not absolutely necessary.

Wherever tried, the open air school has proven so uniformly beneficial to the children that its use is no longer a question of debate.

A convenient form of such a school, in which the success of the method has been adequately demonstrated, is that shown in the cut of the St. Louis Open Air School, herewith presented.

B. S. Warren of the United States Public Health Service in a report on the education of tuberculous children in 1912 gives following testimony to the value of the open air school: "The progress in their grades is remarkable, even though they work little more than half the time. As compared with the children of the public school, they not only keep up in the grades but many (nearly 50 per cent.) go ahead. The St. Louis open air class completed in eight months' time the usual amount of work done in the public schools and 20 per cent. more: in other words, they did in eight months the work that the normal child in the indoor public school would do in nine and one-half months. One class of New York City which was 19 per cent. below grade on admission in October was only 9 per cent. below the following June, making the normal progress plus 10 per cent. more than the child of the public schools. They never seem to fag and are as ready to do arithmetic in the afternoon as in the morning and are as fresh and alert when dismissed as on arrival."



L.H. WILDER (AFTER J. HAL. LYNCH Co. ARCHITECTS)

FIG. 284.—Showing floor plan and west elevation of St. Louis Open-Air School. A good illustration of type of real out-door school.

Dr. Warren also makes an observation which confirms the wisdom of an all around the year school. He says, "During vacations some loss was almost invariably shown, but where records were carefully kept they never showed a loss of all the gain. Tables of weekly weights show slight loss at the beginning of the summer before vacation. This same loss is shown in the controls of healthy children of the public schools."

We have always argued in favor of continuous school work the year around. Not only is the number of hours per day small, but both the children's condition and their progress argue for an uninterrupted school year.

The extent to which Germany has gone ahead of this country is indicated in the article by Dr. McMurtrie previously referred to. In describing some of the institutions, hospital care is simply taken for granted. In each case the training and educational feature of the institution is the thing emphasized. He says regarding one institution, "There is no school, but the boys are taught orthopedic mechanics, key making, saddlery, tailoring, and shoe making." Of another he says, "There is no elementary instruction, although provision is made for advanced training and the making of card board boxes and paper bags." In another institution capable of caring for 24 boys and 20 girls between the ages of 5 and 16 he says, "The single class is conducted by three teachers and a teacher of manual training. The boys are taught bookbinding, paste board work, chair caning, wood working, fret sawing, and tailor's mending; and the girls are instructed in sewing, machine embroidery, mending and the making of artificial flowers."

The great variety of occupations taught in schools for crippled children in Germany serves to illustrate not only the results of the careful study of this problem, but the wide range of usefulness open to crippled individuals if proper training is available.

BOYS

Agriculture
Apparatus, orthopedic, making of
Architectural drawing
Bandage, making
Basketry
Bookbinding
Brush making
Cabinet making
Carpentry
Carving
Carving, chip
Chair caning
Commercial training
Dentistry
Drawing of agricultural plans
Embroidery, machine
Gardening
Glaziers' work
Instrument making
Key making
Knitting, hand

GIRLS

Artificial flowers, making of
Basket weaving
Bookkeeping
Chair caning
Commercial operations
Cooking
Dressmaking
Embroidery, art
Embroidery
Hand work
Housekeeping
Knitting
Knitting, machine
Lace work
Manual work
Mending
Photography
Roentgenographic
Sewing, machine
Sewing, plain
Stenography

Knitting, machine
Lithography
Mat making
Mat weaving
Mechanics
Natural wood work
Net making
Office work
Orthopedic mechanics
Painting
Painting, house
Paper boxes, making
Paste board boxes, making
Paste board work
Photography
Portfolios, making of
Printing
Saddlery
Sail making
Sawing, fret
Sawing, wood
Sewing
Sculpture
Shoemaking
Shoes, making of wooden
Stenography
Tailoring
Tinsmithing
Turning
Typewriting
Wood working
Writing
Trained to become teachers of smaller children
Typewriting
Weaving

An essential preliminary to this educational work, as well as to the work of caring for cripples in general, is to ascertain the number and condition of the children requiring special care. The school census should be required to include diseased and crippled children who, instead of being neglected as they are at present, should by all means be provided with the necessary facilities for their care and education. Transportation to the school and return should of course be provided, thus insuring the best attendance and maximum benefit both educationally and physically.

The varieties of crippled conditions which appear as a result of the diseases previously referred to should be taken into consideration. Tuberculosis, for instance, gives us patients with short extremities and stiffened joints, even after the best treatment that can be obtained. Furthermore, there is always the possibility in tuberculosis of a recurrence of the acute symptoms and acute disease. Such patients must be guarded while in school or at work against traumatism caused by standing, walking, or injury in other ways. Infantile paralysis gives us patients with weakened or entirely useless arms or legs. Such children must have an opportunity for employment in a small area with the minimum of physical exertion. The congenital deformities and various traumatic deformities give us a class of people who must find employment in which they can become proficient and efficient even without the use of one or both feet, legs or arms. All of these problems, which present almost insurmountable difficulties under conditions provided for the care and education of normal individuals, become relatively simple in a special institution. The actual expenditure in caring for a cripple is really but little greater than for a normal individual. It seems larger simply because the money must be diverted into different channels especially for the purpose.

In 1922 we must take account of the great achievements of our Federal Government in the after care and vocational retraining of those who were crippled in our military effort in France. One must say, however, that progress in similar care for crippled children and those disabled in the industries is still relatively slow. Interest is being aroused and better hospital care and more special schools may soon be developed.

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